

**NASA TECHNICAL
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NASA TM X-71984
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NASA TM X-71984

(NASA TM-X-71984) STABILITY AND CONTROL
CHARACTERISTICS OF A MONOPLANE MISSILE
WITH LARGE DELTA WINGS AND VARIOUS TAIL
CONTROLS AT MACH 1.90 TO 2.86 (NASA)
41 p HC \$3.25

N74-29291

CSCL 16D G3/31 Unclass
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STABILITY AND CONTROL CHARACTERISTICS OF A MONOPLANE
MISSILE WITH LARGE DELTA WINGS AND VARIOUS TAIL
CONTROLS AT MACH 1.90 TO 2.86

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**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LANGLEY RESEARCH CENTER, HAMPTON, VIRGINIA 23665**

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MISSILE WITH LARGE DELTA WINGS AND VARIOUS TAIL
CONTROLS AT MACH 1.90 TO 2.86**

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SUMMARY

An investigation has been conducted to determine the aerodynamic characteristics, including control effectiveness, of a monoplane delta wing missile model with various tail-control configurations at Mach numbers from 1.90 to 2.86. The cruciform tail configuration exhibits the greatest pitch-control effectiveness; however, relatively large nonlinear pitching moment characteristics are experienced due to the effects of the wing wake. The cruciform tail controls provide the greatest yaw-control effectiveness. The three-fin configuration with the lower vertical tail shows a substantial increase in control effectiveness as angle of attack is increased, whereas the configuration with the upper vertical tail exhibits a small decrease. With four fins deflected, the cruciform tail produces approximately double the rolling-moment coefficient of the three-fin configuration with only the horizontal fins deflected. Roll-control effectiveness is essentially invariant with angle of attack. For a forward movement of the moment reference center of about one body diameter, all configurations would provide adequate directional stability, with the magnitude of the directional stability being greatest for the cruciform configuration and least for the three-fin upper-vertical-tail configuration.

INTRODUCTION

The National Aeronautics and Space Administration is currently conducting aerodynamic studies of various short-range air-to-air and ground-to-air type missile configurations in order to provide an insight into the potential for improving performance and maneuverability. The results of recent investigations of several cruciform-wing configurations at transonic and supersonic speeds are reported in references 1 to 4. An alternate concept to the conventional cruciform arrangement would be the use of monoplanar wings with the possibility of reducing drag and weight. However, some questions arise such as the effects on maneuverability since the monoplanar missile, in some

cases, must roll to align the lift vector with the plane of anticipated flight paths prior to performing a maneuver, whereas the cruciform missile is not required to roll before changing flight planes. Another important aspect with regard to maneuverability is that of control surface design. A restriction on the geometry of air-to-air missiles is sometimes imposed by the storage space on the carrying airplane. The missile must be designed to fit within these confines and also maintain sufficient clearance of the airplane during launch. These stowage and launch restrictions, however, generally afford numerous options of wing and tail size and location.

In order to aid in the assessment of missile configurations, a study was undertaken to determine the stability and control characteristics of a monoplane-wing missile configuration incorporating several tail-control arrangements. The investigation utilized the cruciform blunt-nose model of reference 4 with one set of wing panels removed. Tail-control configurations investigated were interdigitated-cruciform (4 panels inclined 45° to the horizontal and vertical planes), a conventional airplane type (2 horizontal panels and an upper vertical panel), and an inverted conventional type (2 horizontal panels and a lower vertical panel). Data were obtained at Mach numbers from 1.90 to 2.86 and Reynolds numbers from about 3.3×10^6 to 6.6×10^6 per meter.

SYMBOLS

The longitudinal and lateral data are referred to the stability and body-axes systems, respectively. The moment center is located at 60 percent of the body length, measured from the apex of the previously investigated conical nose (see fig. 1 and refs. 3 and 4).

A maximum body cross-sectional area, 0.004560 m^2

C_D drag coefficient, $\frac{\text{Drag}}{qA}$

C_L lift coefficient, $\frac{\text{Lift}}{qA}$

C_ℓ rolling-moment coefficient, $\frac{\text{Rolling moment}}{qAd}$

C_m pitching-moment coefficient, $\frac{\text{Pitching moment}}{qAd}$

C_n	yawing-moment coefficient, $\frac{\text{Yawing moment}}{qAd}$
C_Y	side-force coefficient, $\frac{\text{Side force}}{qA}$
d	maximum body diameter, 7.620 cm
M	Mach number
q	dynamic pressure
α	angle of attack, deg
δ_ℓ	individual tail deflections to provide roll (negative deflection for positive moment; all tails deflected on four-fin configurations, only horizontal tails deflected on three-fin configurations), deg
δ_m	individual tail deflections to provide pitch (negative deflection for positive moment, all tails deflected except those in vertical plane), deg
δ_n	individual tail deflections to provide yaw (negative deflection for positive moment, all tails deflected except those in horizontal plane), deg
ϕ	model roll angle about body center line (see fig. 1)

APPARATUS

Model

Details of the model are shown in figure 1. The basic configuration consisted of a spherically-blunted ogive forebody, a cylindrical afterbody, and monoplane delta-planform wings with modified hexagonal sections and circular leading- and trailing-edge bluntness. The hypothetical wing planform is shown by the dashed line in order to indicate the degree of edge bluntness. The tail-control configurations tested were (1) a cruciform arrangement (four fins) with fins in planes inclined 45° to the horizontal and vertical planes,

(2) an inverted three-fin arrangement (two horizontal fins and a lower vertical fin), and (3) a conventional three-fin arrangement (two horizontal fins and an upper vertical fin). The tail edges were relatively sharp.

Wind Tunnel

The investigation was conducted in the low-speed leg of the Langley Unitary Plan wind tunnel, which is a variable-pressure, continuous-flow facility. The test section is approximately 1.22 meters square by 2.13 meters long. The nozzle leading to the test section is of the asymmetric sliding-block type, which permits a continuous variation in Mach number from about 1.5 to 2.9.

MEASUREMENTS, CORRECTIONS, AND TEST CONDITIONS

Aerodynamic forces and moments were measured by means of a sting-supported, six-component, strain-gage balance mounted within the model. The tests were conducted at Mach numbers from 1.90 to 2.86 for angles of attack to approximately 24° . The Reynolds number ranged from about 3.3×10^6 to 6.6×10^6 per meter.

The angles of attack have been corrected for tunnel flow angularity and the deflection of the model support system due to load. The drag coefficient has been adjusted to a condition of free-stream static pressure at the model base. The stagnation dew point was maintained sufficiently low to insure negligible condensation effects.

Boundary layer transition strips composed of carborundum grains embedded in a plastic adhesive were affixed to the wing and tail surfaces and the nose. The strips were 0.15 cm (0.06 in.) wide and consisted of No. 45 grains located 1.02 cm (0.40 in.) rearward of the wing and tail leading edges and 3.05 cm (1.20 in.) rearward of the blunt nose stagnation point, measured parallel to the model centerline.

PRESENTATION OF RESULTS

The results are presented in the following figures:

	Figure
Pitch control characteristics, $M = 1.90$	2
Pitch control characteristics, $M = 2.36$	3
Pitch control characteristics, $M = 2.86$	4
Summary of pitch control characteristics for inverted and cruciform tails, $M = 2.36$	5
Yaw control characteristics	6
Roll control characteristics	7
Aerodynamic characteristics in sideslip, $M = 1.90$	8
Aerodynamic characteristics in sideslip, $M = 2.36$	9
Aerodynamic characteristics in sideslip, $M = 2.86$	10

DISCUSSION

The pitch control deflection characteristics for the various configurations are presented in figures 2 to 4 for Mach numbers of 1.90, 2.36, and 2.86, respectively. The effects of the variation in tail-control geometry on the lift and drag characteristics are of the expected trends and magnitudes and, hence, will not be discussed in detail.

The pitching-moment data at $M = 2.36$, which are indicative of the general trends for the Mach number range investigated, are summarized in figure 5 as a function of angle of attack. This comparison gives an indication of the differences in linearity and in control effectiveness for the horizontal and the cruciform controls. The pitching moment characteristics for the configurations incorporating horizontal pitch controls are generally more linear than those for the cruciform tails since the upper cruciform surfaces, in particular, are affected by the wing wake. As would be expected, the cruciform control configuration (all panels deflected) provides greater pitch-control effectiveness. However, for a constant angle of attack with pitch controls deflected, the horizontal tail control provides higher lift and lower drag than does the cruciform tail control.

The variation of the yaw control characteristics with angle of attack are presented in figure 6. These data exhibit the usual decrease in control effectiveness with increasing Mach number. As expected, the cruciform configuration provides more yaw control than the three-fin configurations. The three-fin configuration with the lower vertical tail shows a substantial increase in control effectiveness as angle of attack is increased, whereas the configuration with the upper vertical tail exhibits a small decrease. These effects reflect the dynamic pressure changes in the flow fields surrounding the respective yaw controls.

The effects of angle of attack on the roll control characteristics are shown in figure 7. The cruciform tail configuration (four fins deflected) provides approximately double the rolling moment coefficient produced by the three-fin configuration (only horizontal fins deflected). The roll control effectiveness is essentially invariant with angle of attack. It should be noted that the cruciform configuration induces a considerable positive yawing moment at the higher angles of attack due to the interference flow fields.

The aerodynamic characteristics in sideslip are presented in figures 8 to 10 for Mach numbers of 1.90, 2.36, and 2.86, respectively. The magnitude of the directional stability is generally greatest for the cruciform configuration and poorest for the three-fin, upper-vertical-tail configuration. However, at $\alpha_{nom} = 20^\circ$, the three-fin, lower-vertical-tail configuration exhibits directional stability that is slightly greater than that provided by the cruciform tail. For the moment center used in data reduction, some of the results indicate directional instability. However, a forward movement of the moment center of only one body diameter is more than enough to provide directional stability for all test conditions for all configurations.

All configurations show a positive effective dihedral ($-C_{l\beta}$) at positive angle of attack. The dihedral effect is generally the greatest for the upper single vertical tail arrangement and is the least for the lower single vertical tail.

CONCLUSIONS

An investigation has been conducted to determine the aerodynamic characteristics, including control effectiveness, of a monoplane delta wing missile model

with various tail-control configurations at Mach numbers from 1.90 to 2.86. The conclusions are summarized as follows:

1. The cruciform tail configuration exhibits the greatest pitch-control effectiveness; however, relatively large nonlinear pitching moment characteristics are experienced due to the effects of the ring wake.
2. The cruciform tail controls provide the greatest yaw-control effectiveness. The three-fin configuration with the lower vertical tail shows a substantial increase in control effectiveness as angle of attack is increased, whereas the configuration with the upper vertical tail exhibits a small decrease.
3. With four fins deflected, the cruciform tail produces approximately double the rolling-moment coefficient of the three-fin configuration with only the horizontal fins deflected. Roll-control effectiveness is essentially invariant with angle of attack.
4. For a forward movement of the moment reference center of about one body diameter, all configurations would provide adequate directional stability with the magnitude of the directional stability being greatest for the cruciform configuration and least for the three-fin upper-vertical-tail configuration.

Langley Research Center,

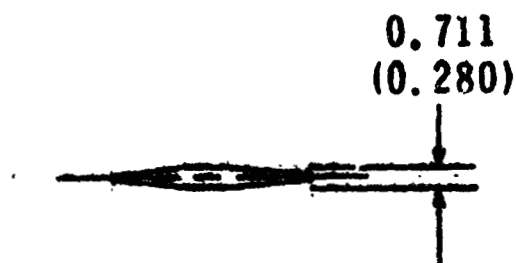
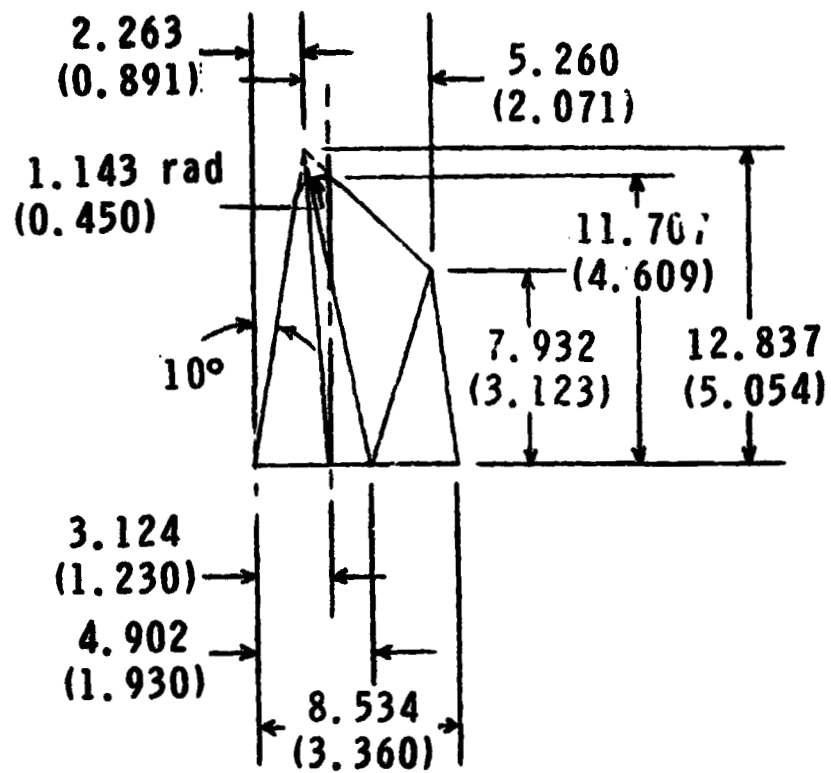
National Aeronautics and Space Administration,

Hampton, Va., July 3, 1974.

REFERENCES

1. Spearman, M. Leroy; and Fournier, Roger H.: Aerodynamic Characteristics of a Maneuverable Missile With Cruciform Delta Wings and Aft Tail Controls at Mach Numbers From 1.50 to 4.63. NASA TM X-1863, 1969.
2. Corlett, William A.: Aerodynamic Characteristics at Mach 2.50 to 4.63 of a Cruciform Missile Model With Delta Wings and Trapezoidal-Tail Controls Including Effects of Wing Location. NASA TM X-2364, 1971.

3. Corlett, William A.; and Howell, Dorothy T.: Aerodynamic Characteristics at Mach 0.60 to 4.63 of two Cruciform Missile Models, one Having Trapezoidal Wings With Canard Controls and the Other Having Delta Wings With Tail Controls. NASA TM X-2780, 1973.
4. Jernell, Lloyd S.; Monta, William J.; and Flechner, Stuart G.: Stability and Control Characteristics of a Cruciform Missile With Large Delta Wings and Aft Tail Controls at Mach Numbers From 0.60 to 4.63. NASA TM X-3037, 1974.



(b) Tail control details.
Figure 1. -Concluded.

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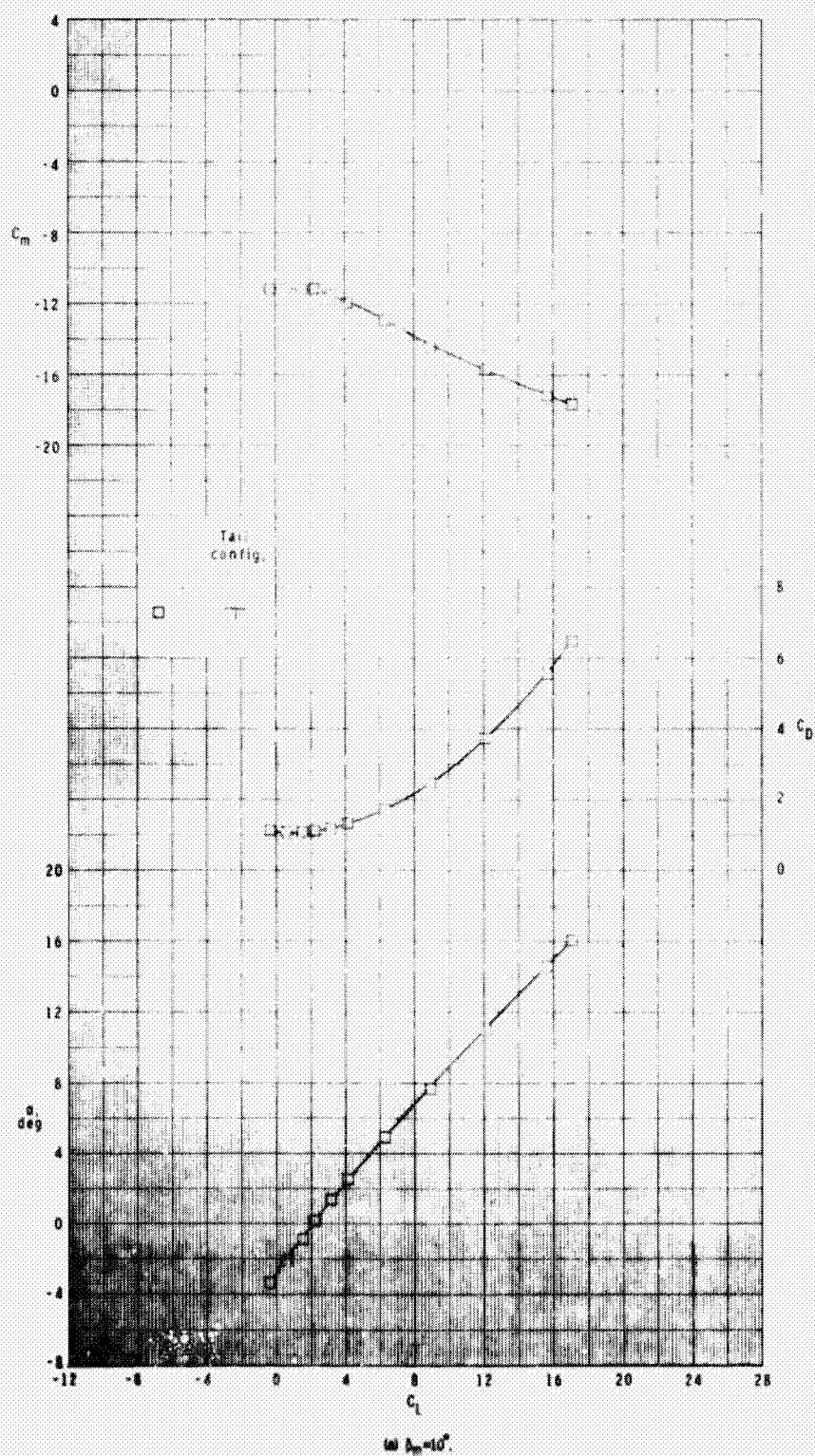
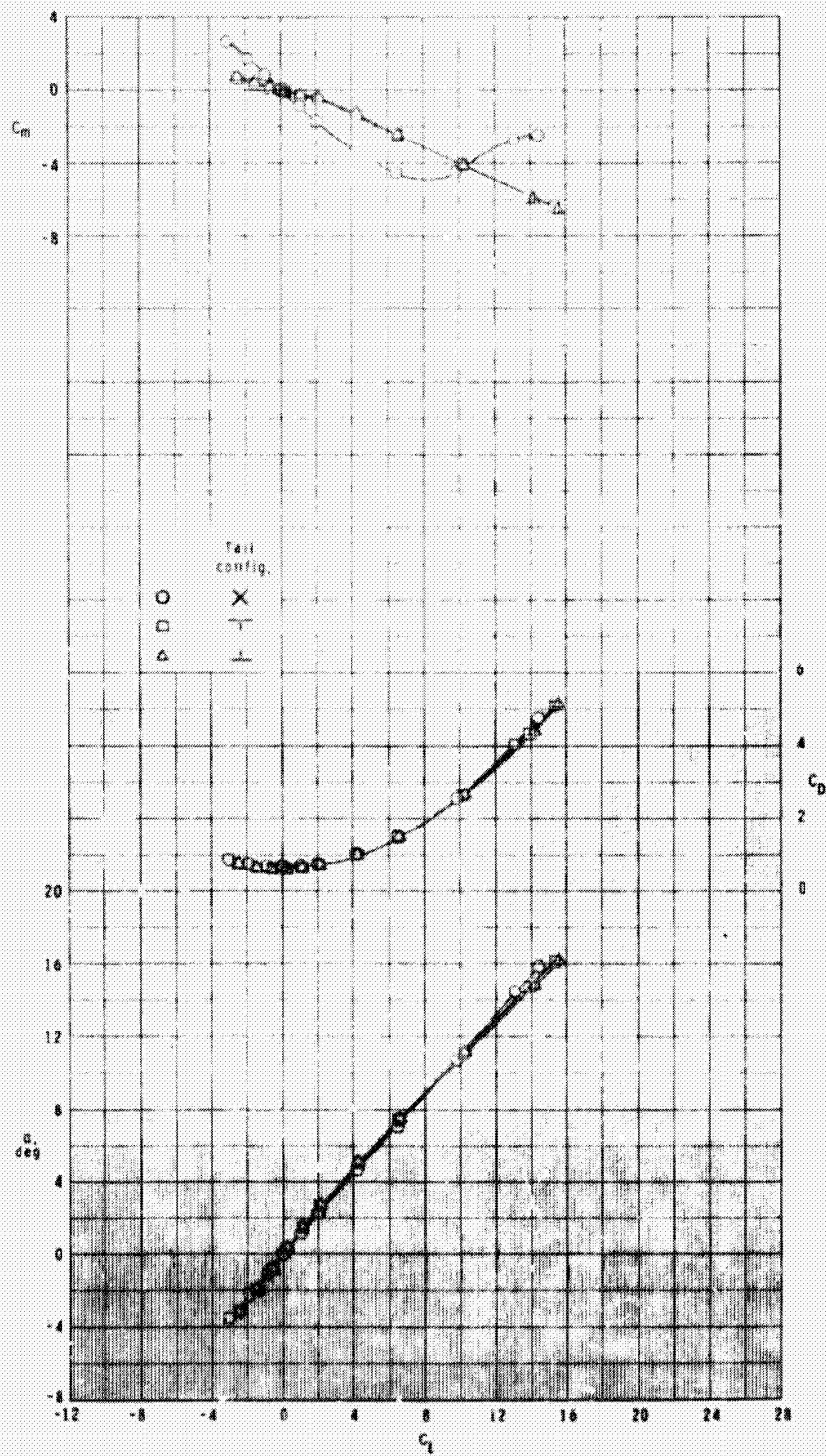


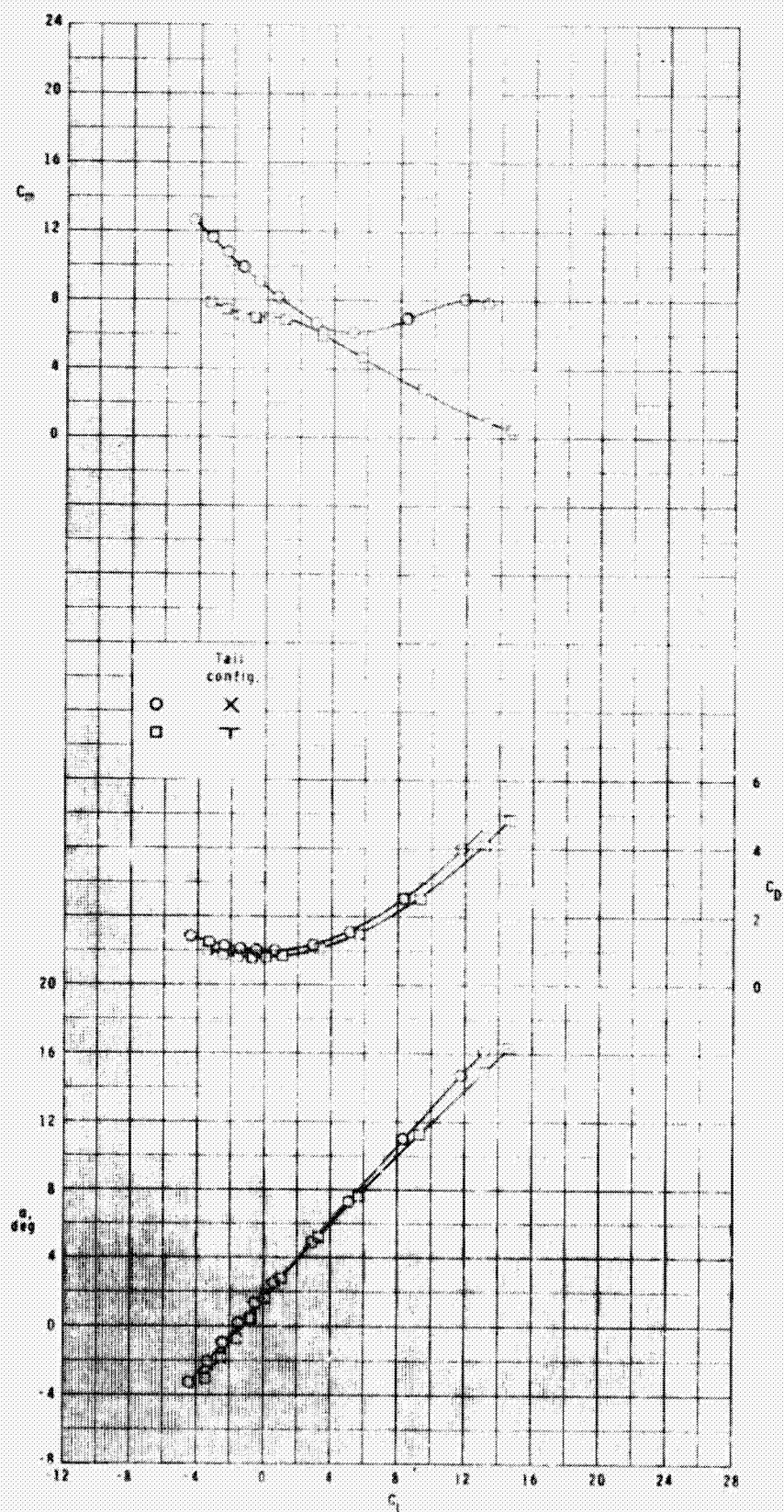
Figure 2 - Lift and drag characteristics, $Re = 10^6$

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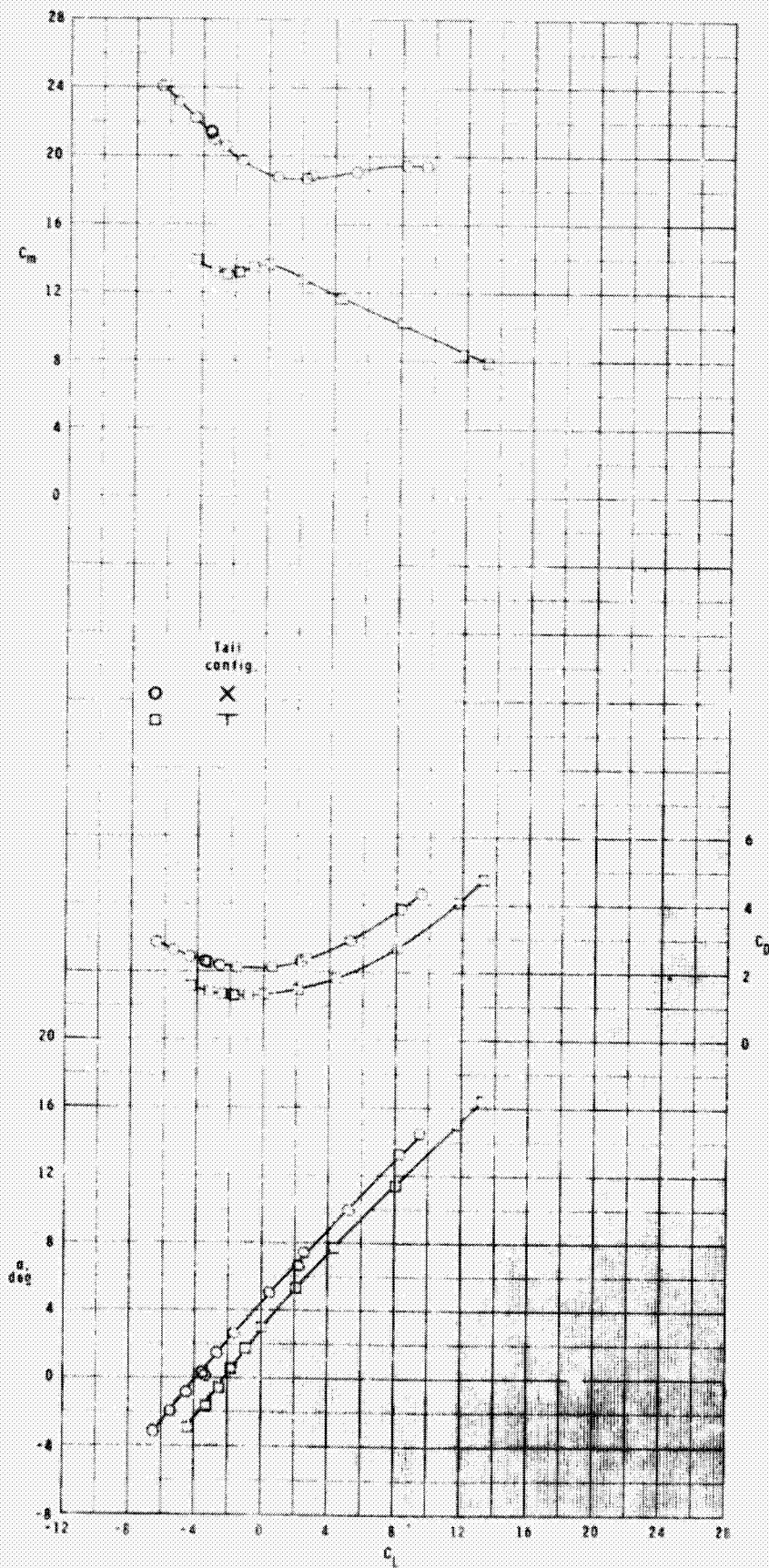
at $\alpha_m = 0^\circ$
Figure 2.- Continued.

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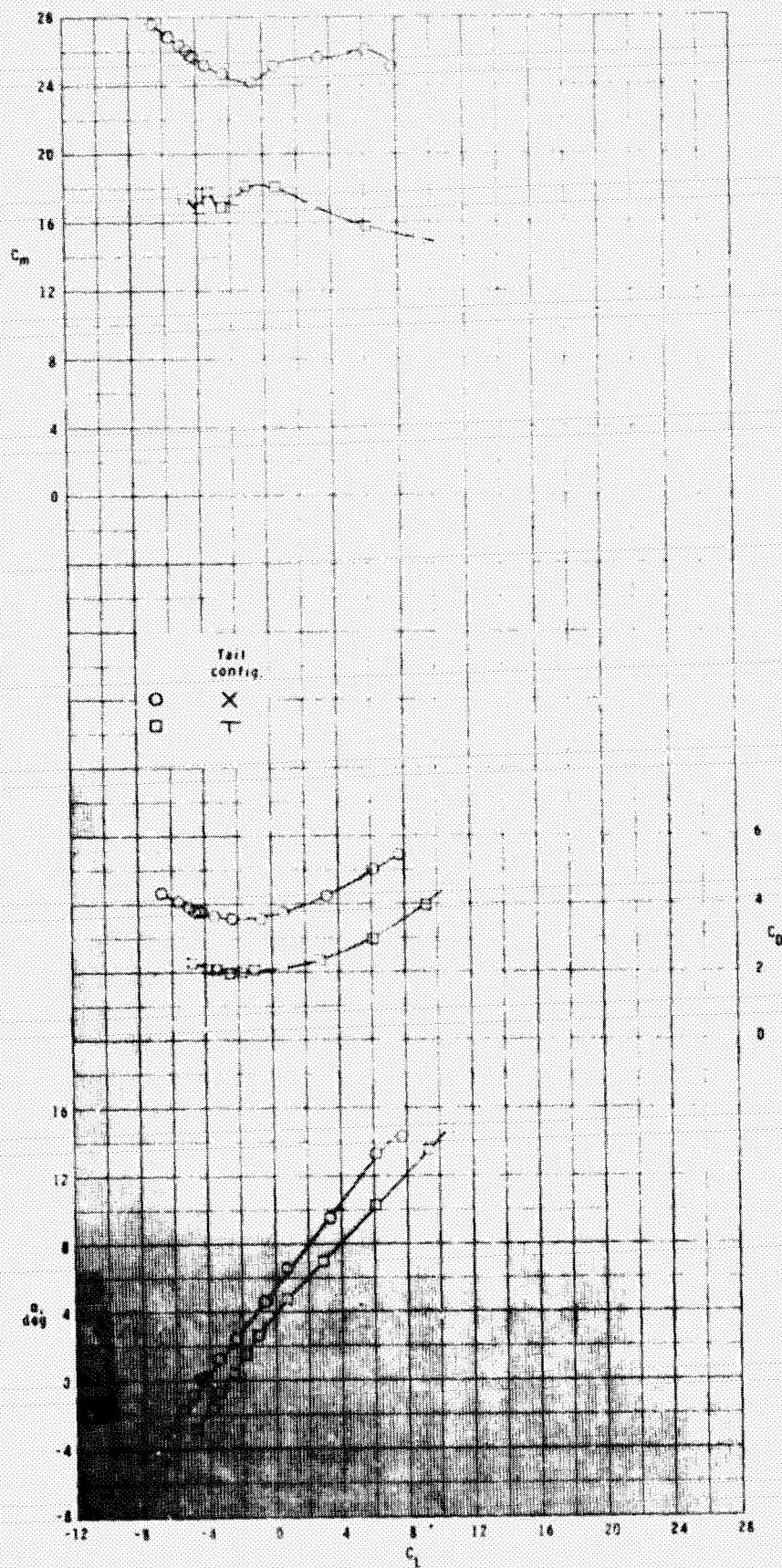
at $\delta_m = -10^\circ$
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(d) $\alpha_m = -20^\circ$.
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(a) $\delta_m = -30^\circ$.
Figure 2.-Concluded.

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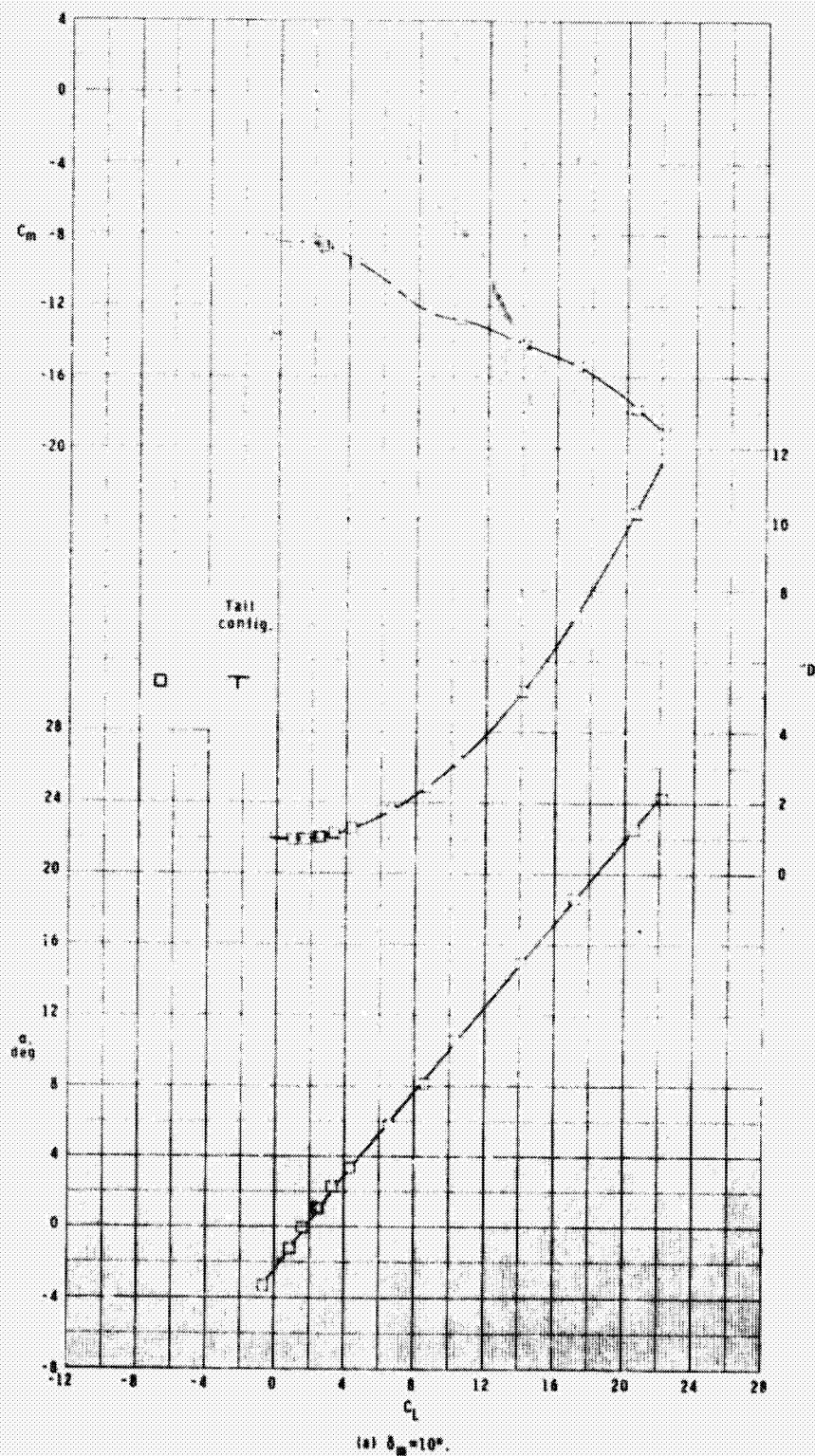


Figure 3.-Pitch control characteristics, $M=2.30$.

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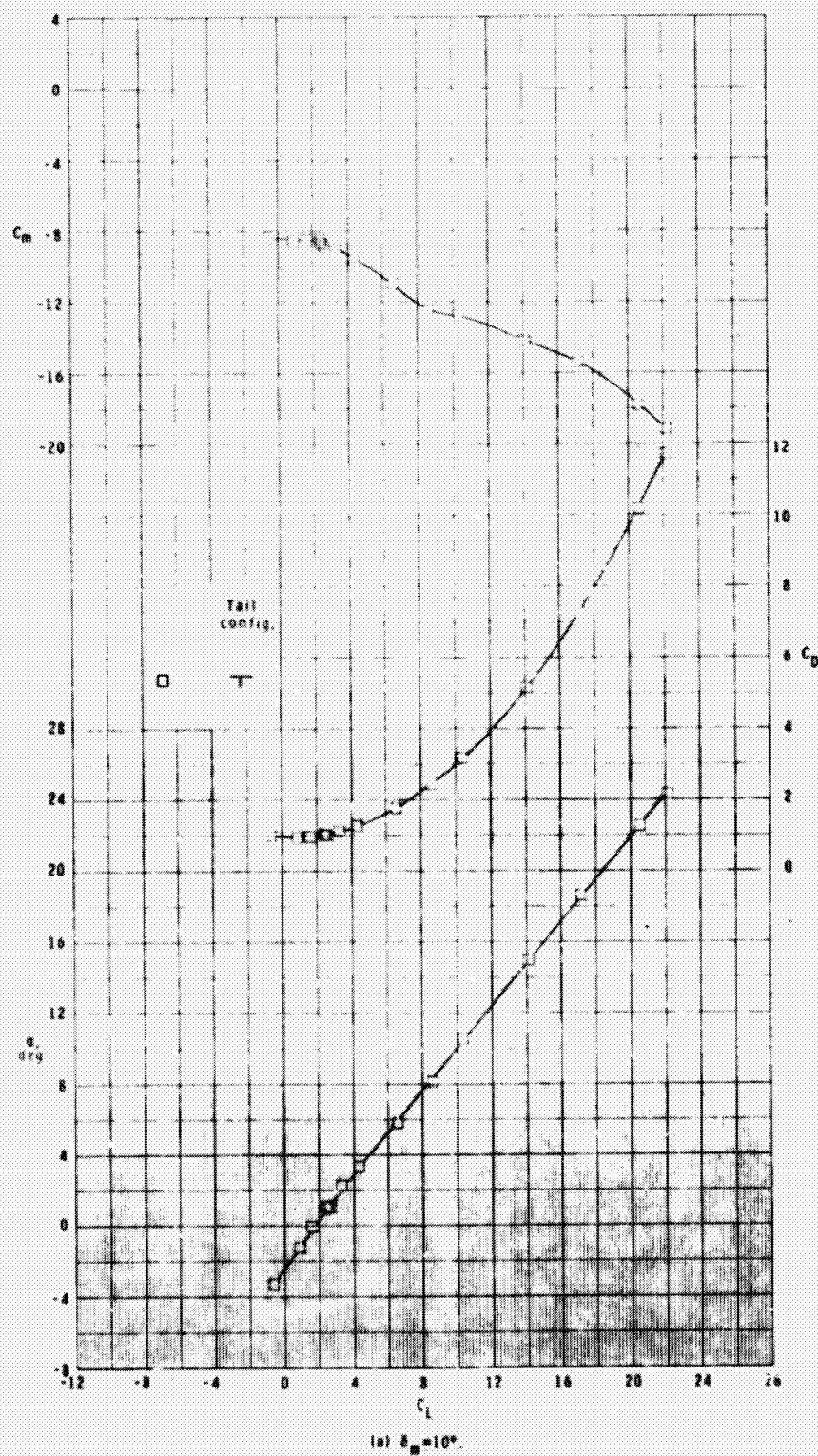
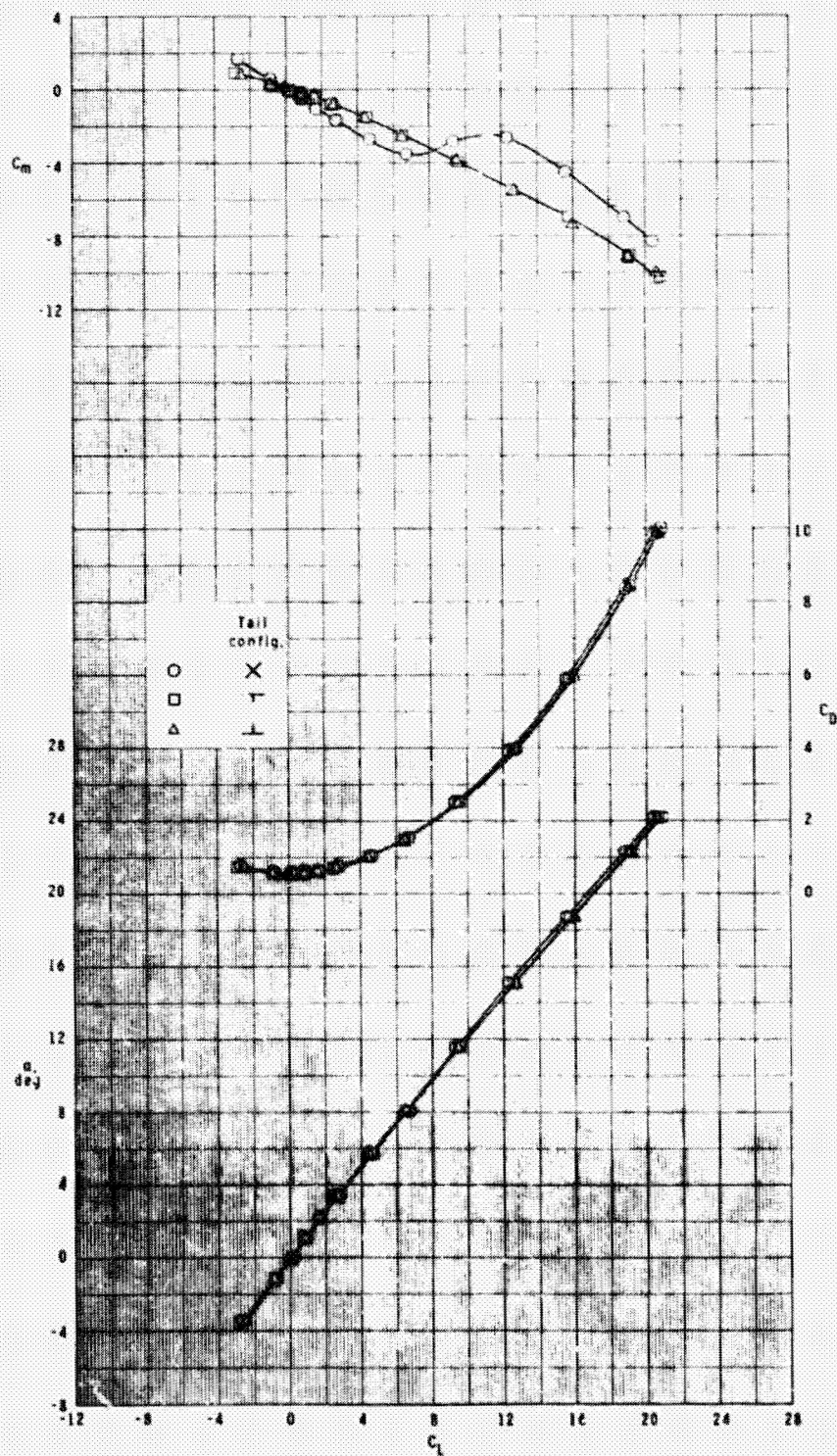


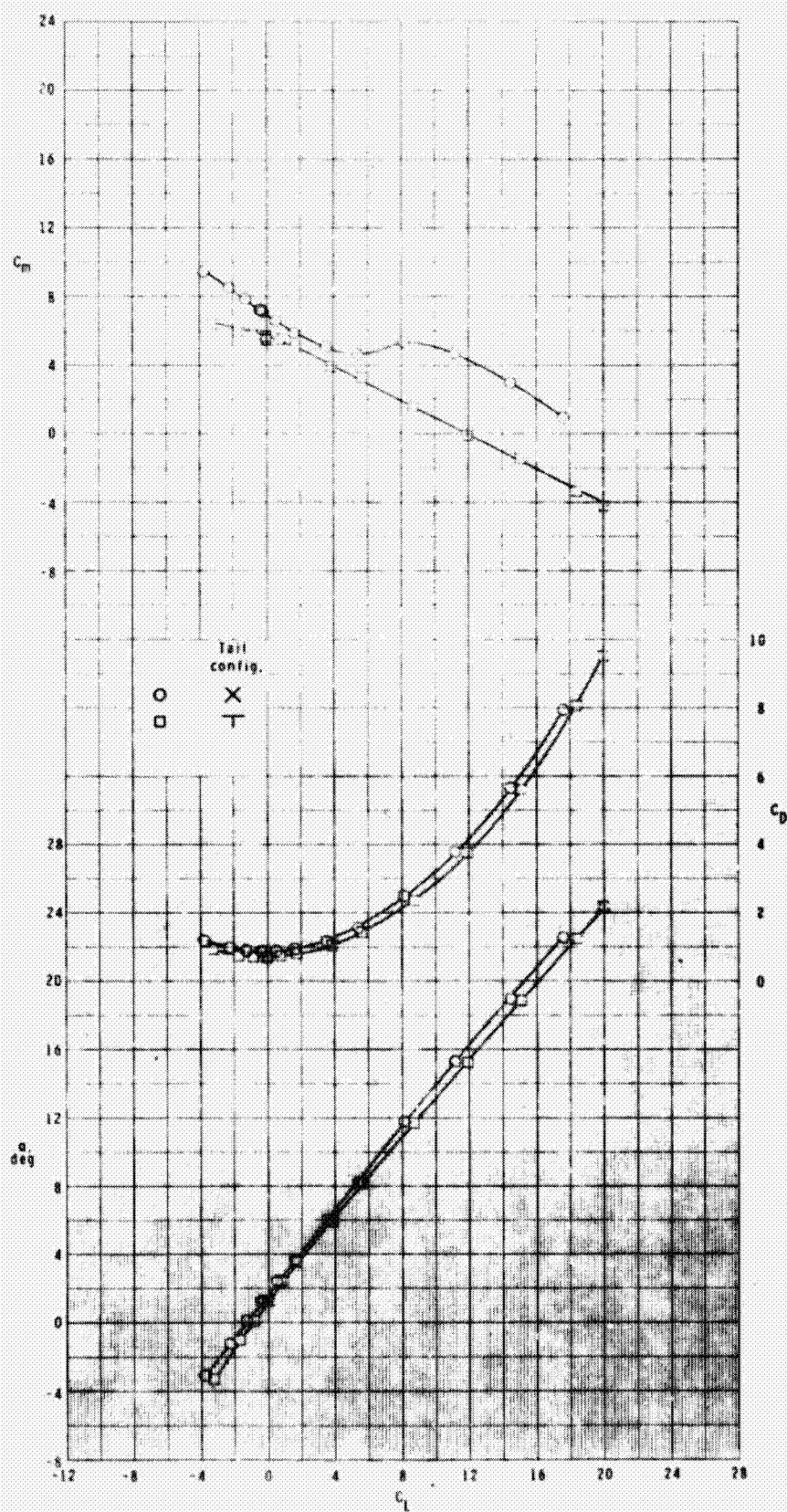
Figure 3. Pitch control characteristics, $M=2.36$.

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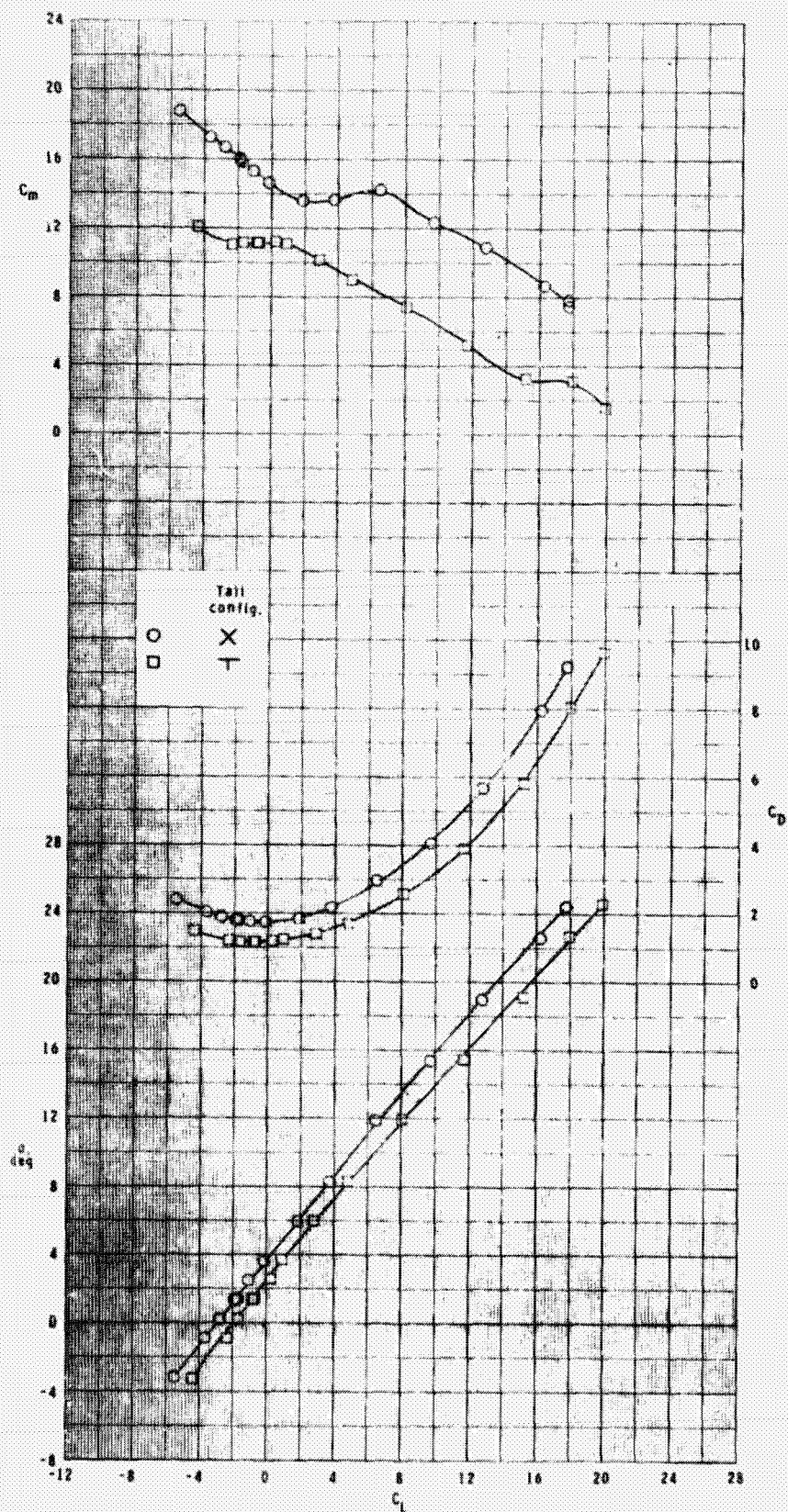
1b1 $\delta_m = 0^\circ$.
Figure 3.-Continued.

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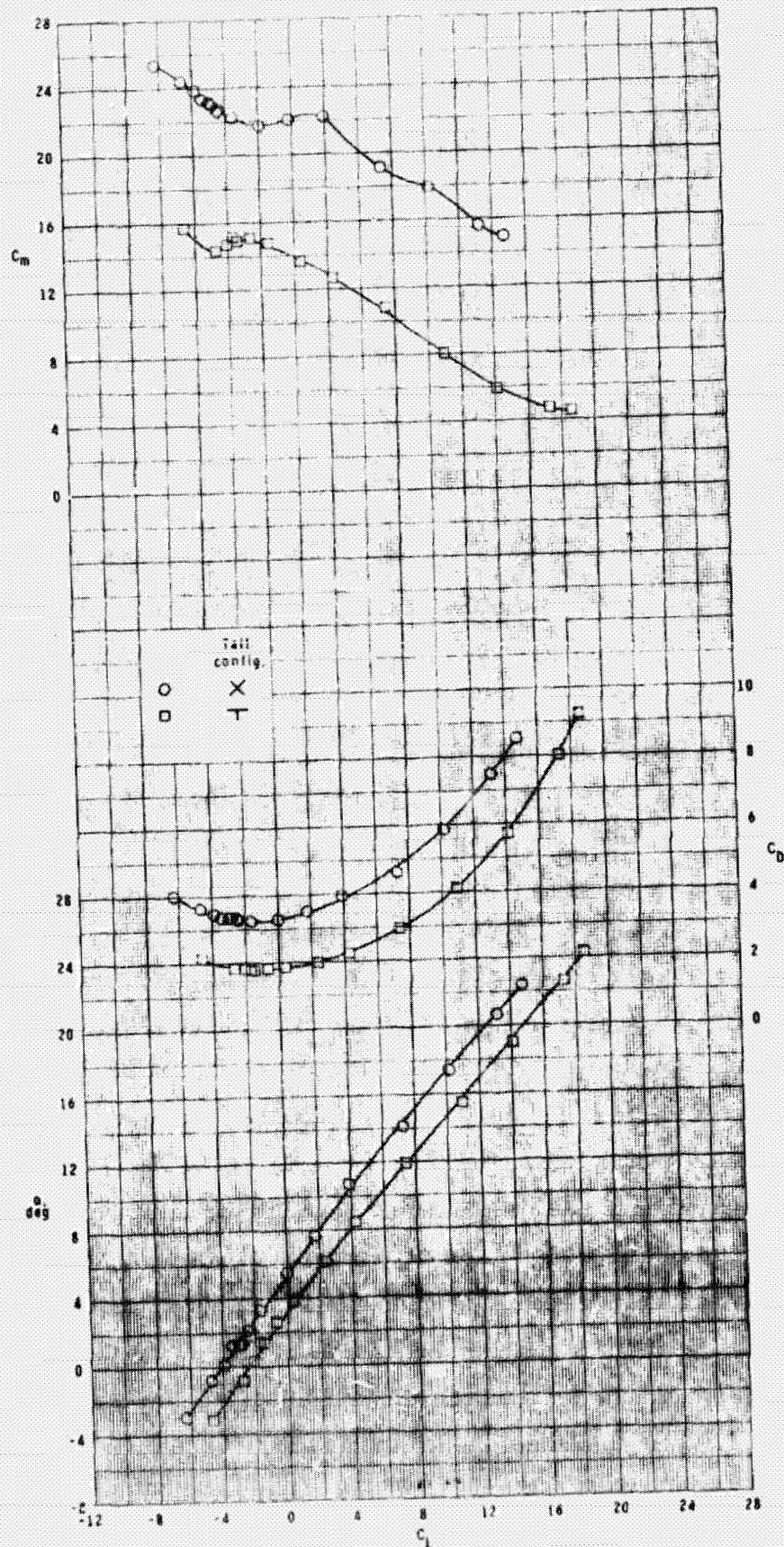
(c) $\delta_m = -10^\circ$.
Figure 3.-Continued.

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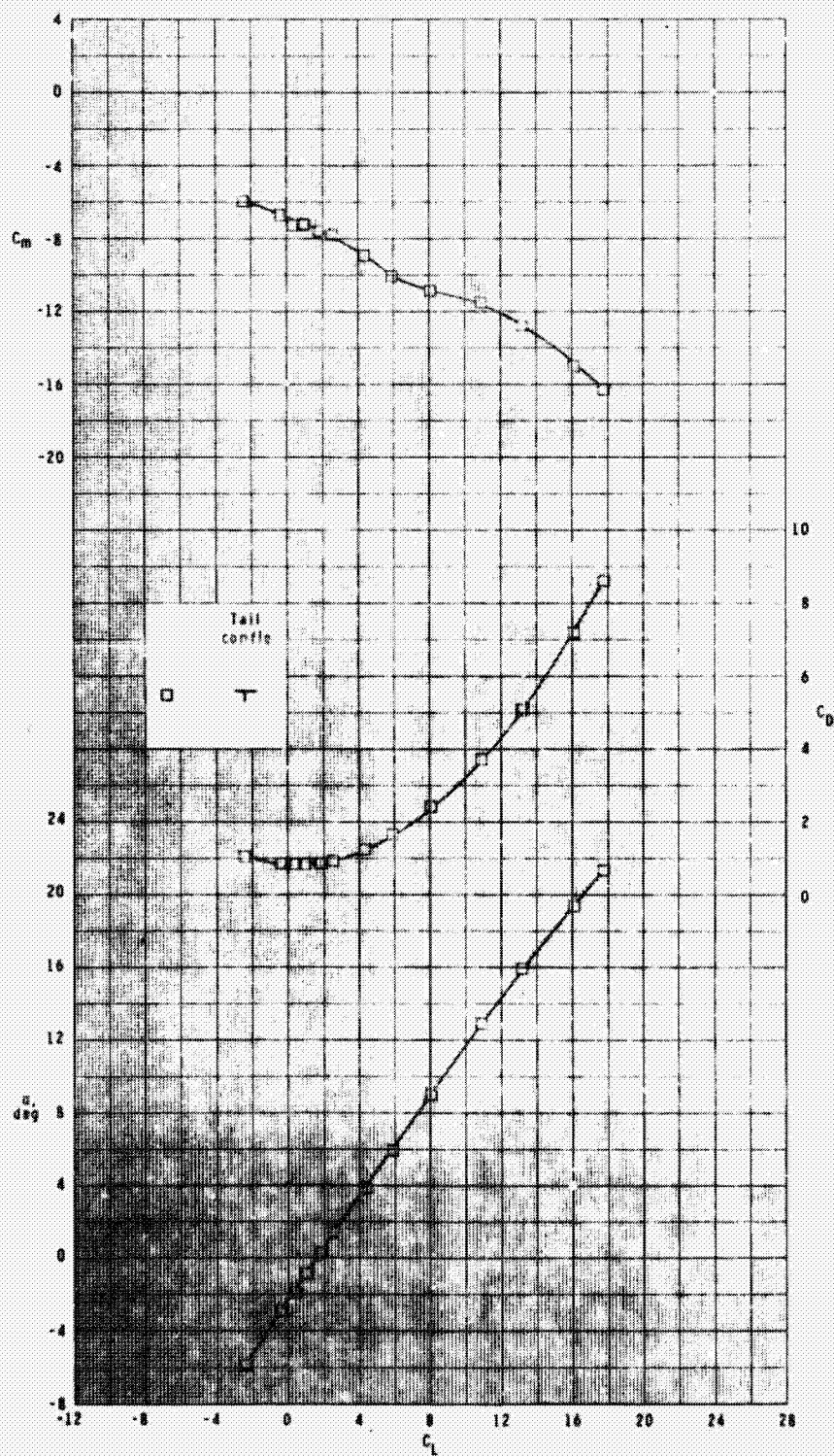
(d) $M_\infty = 20^\circ$.
Figure 3.-Continued.

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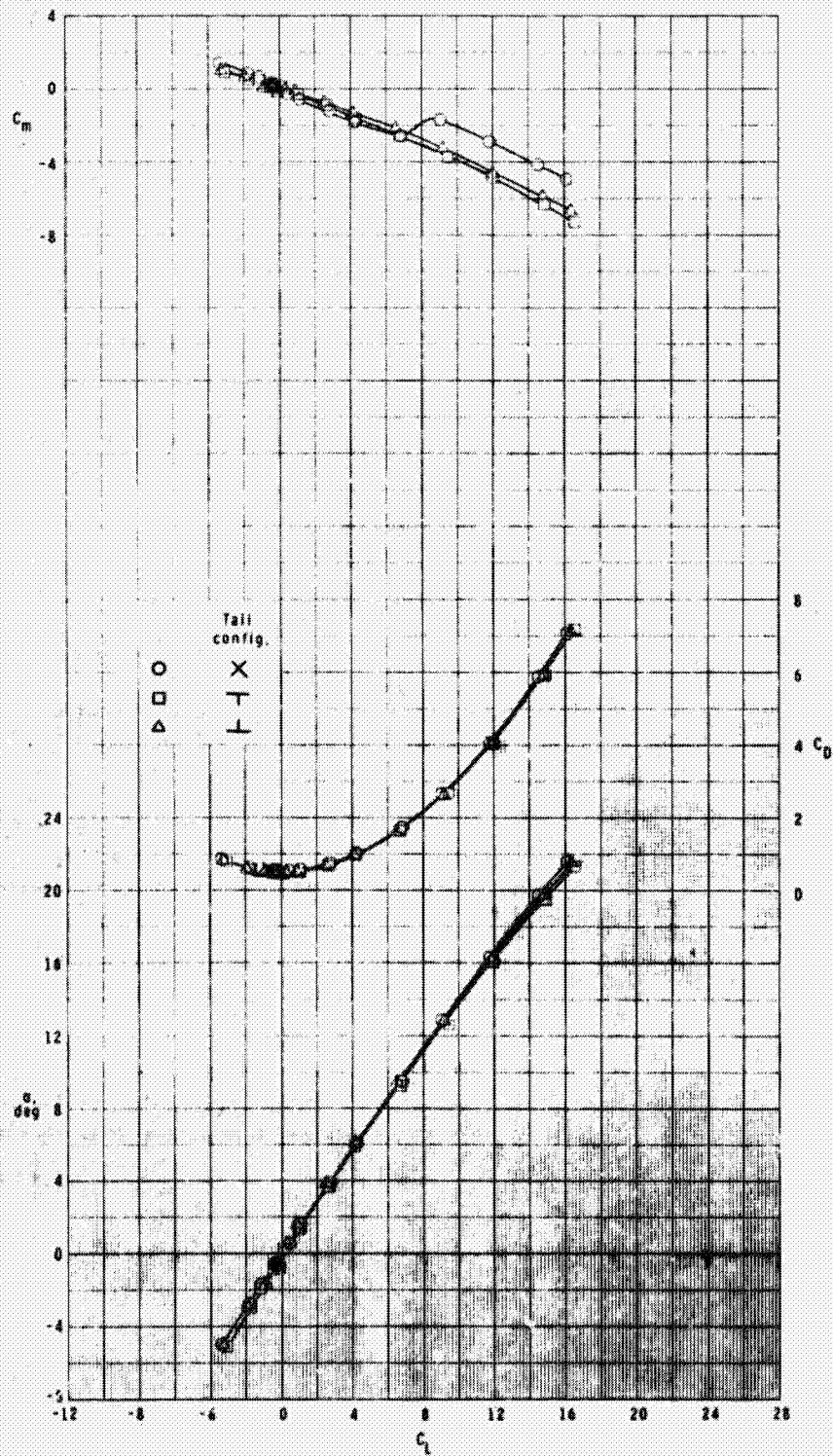
(a) $M_\infty = 0.30$.
Figure 3.- Concluded.

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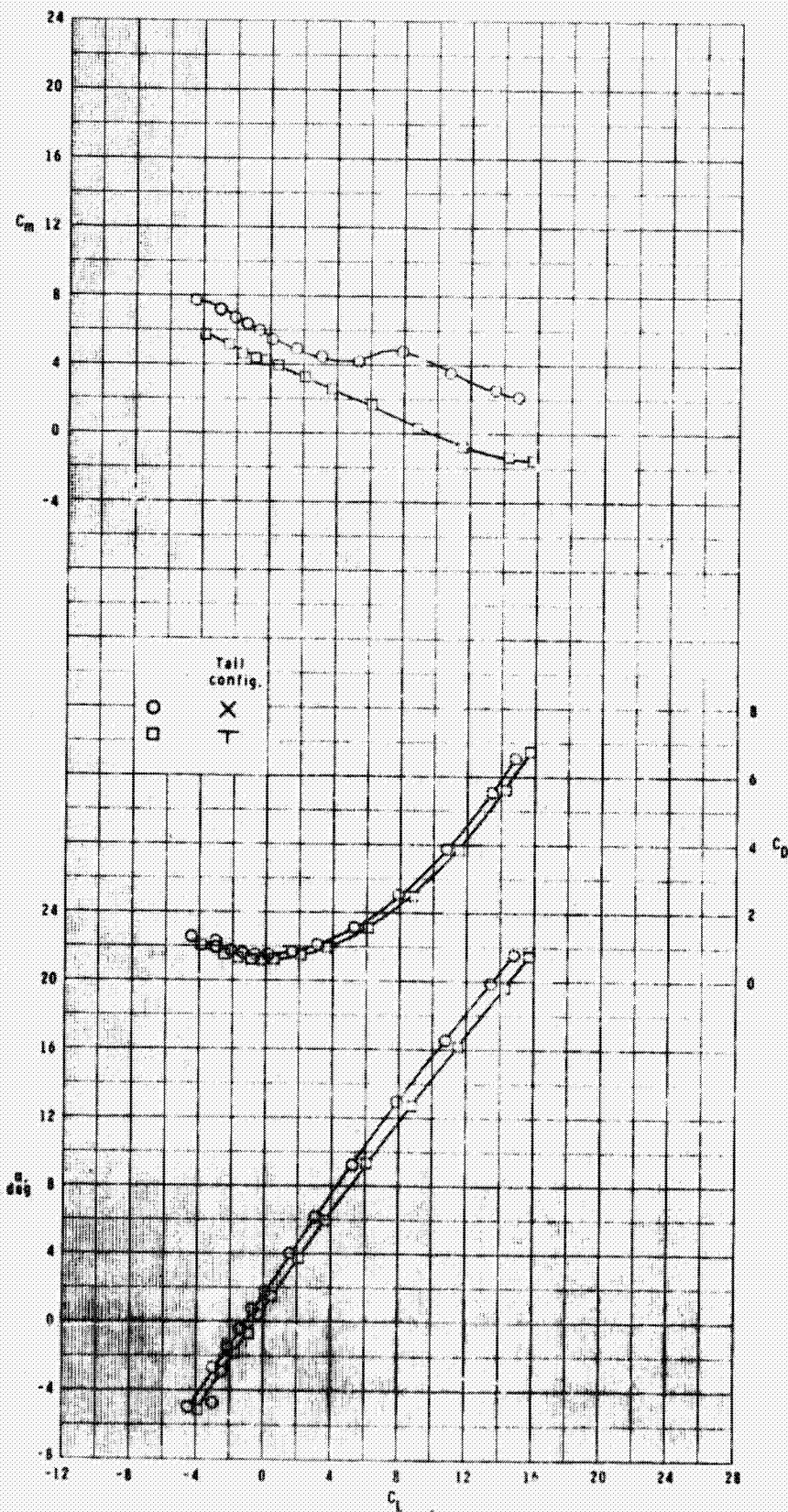
(a) $\delta_m = 10^\circ$.
Figure 4. Pitch control characteristics, $M = 2.86$.

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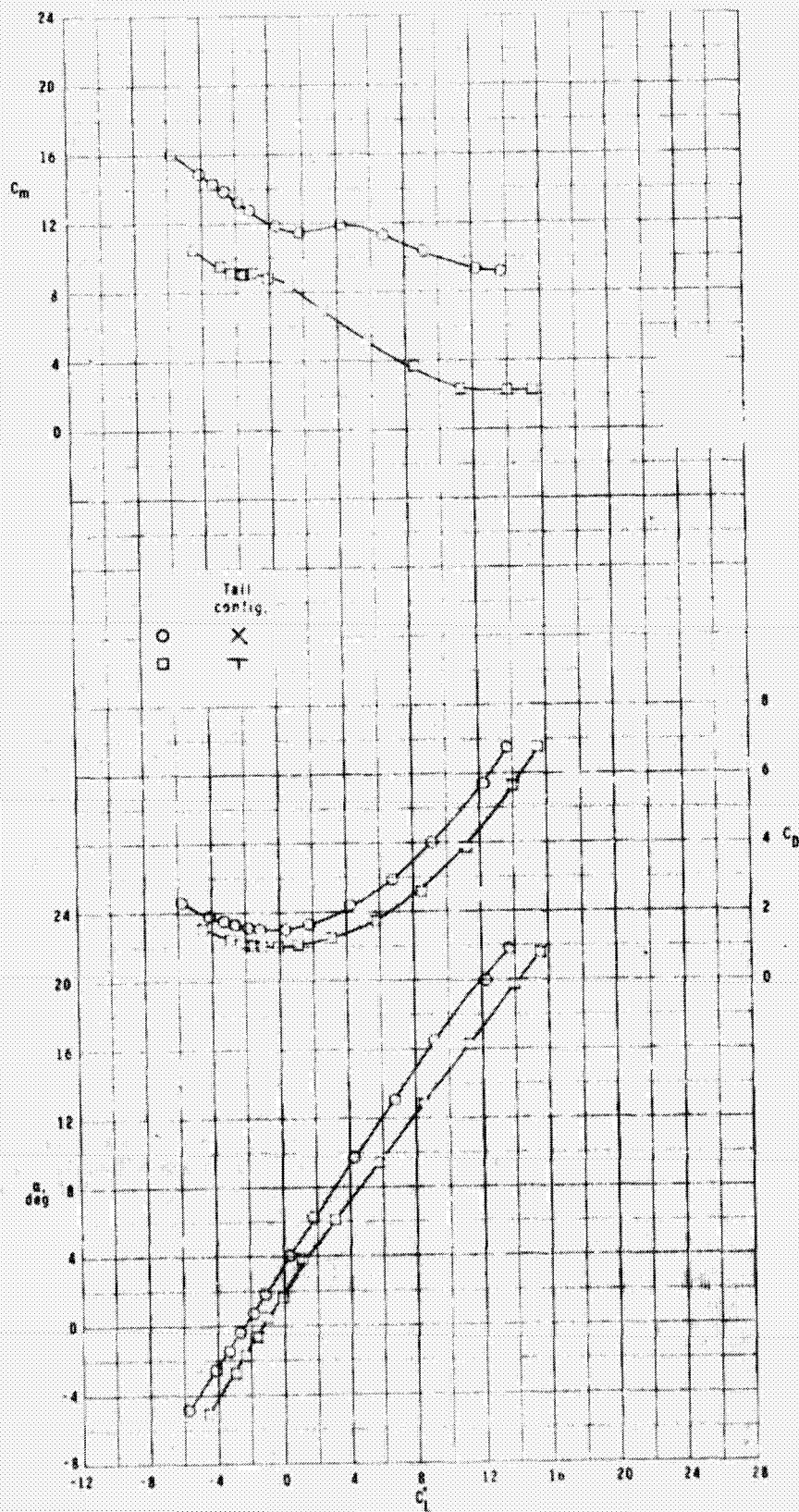
(b) $\delta_m = 0^\circ$.
Figure 4. - Continued.

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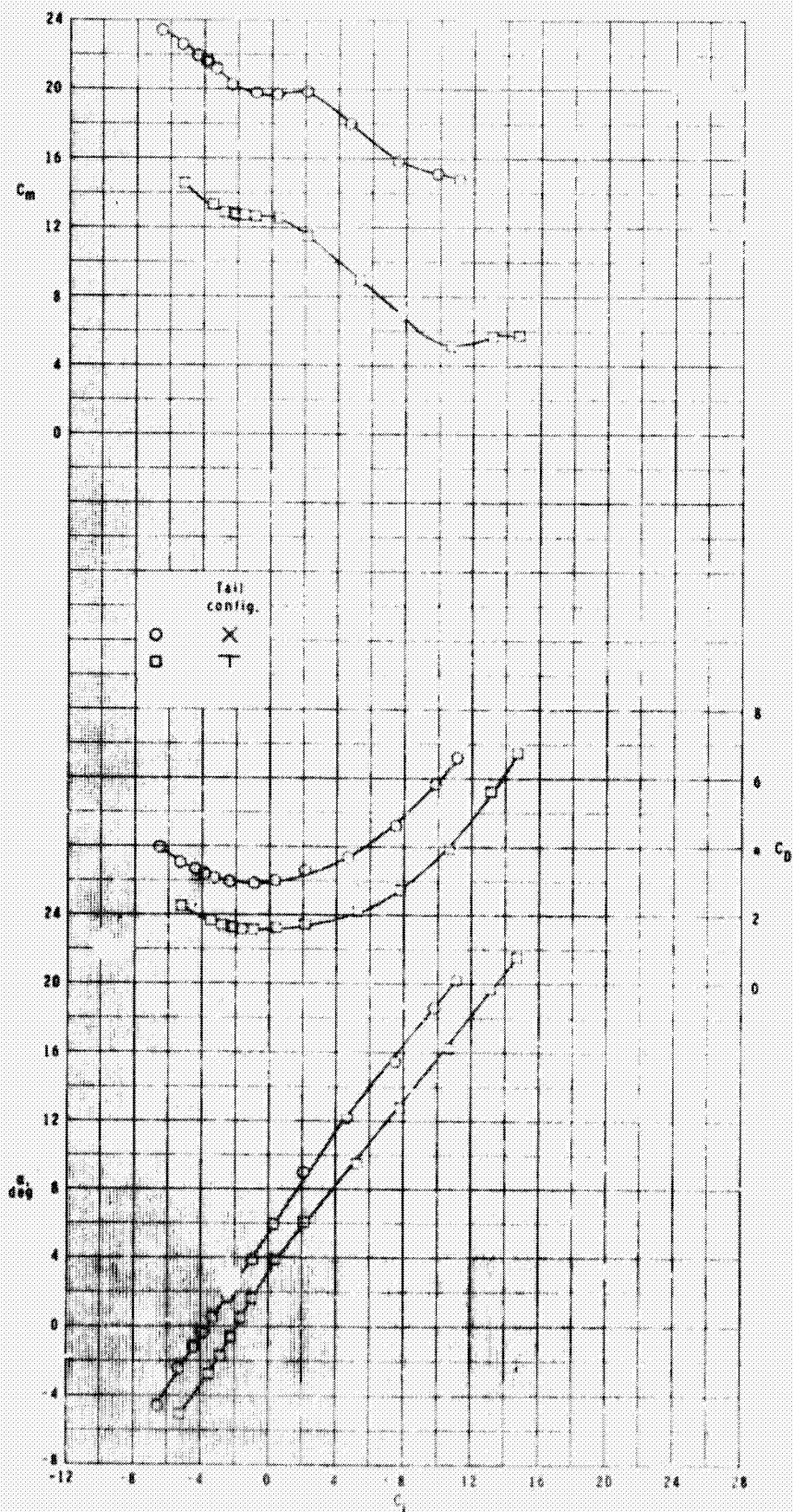
(c) $M_\infty = 10$
Figure 4. Continued.

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(d) $\delta_m = -20^\circ$.
 Figure 4.-Continued.

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(a) $\delta_R = 30^\circ$.
 Figure 4. - Concluded.

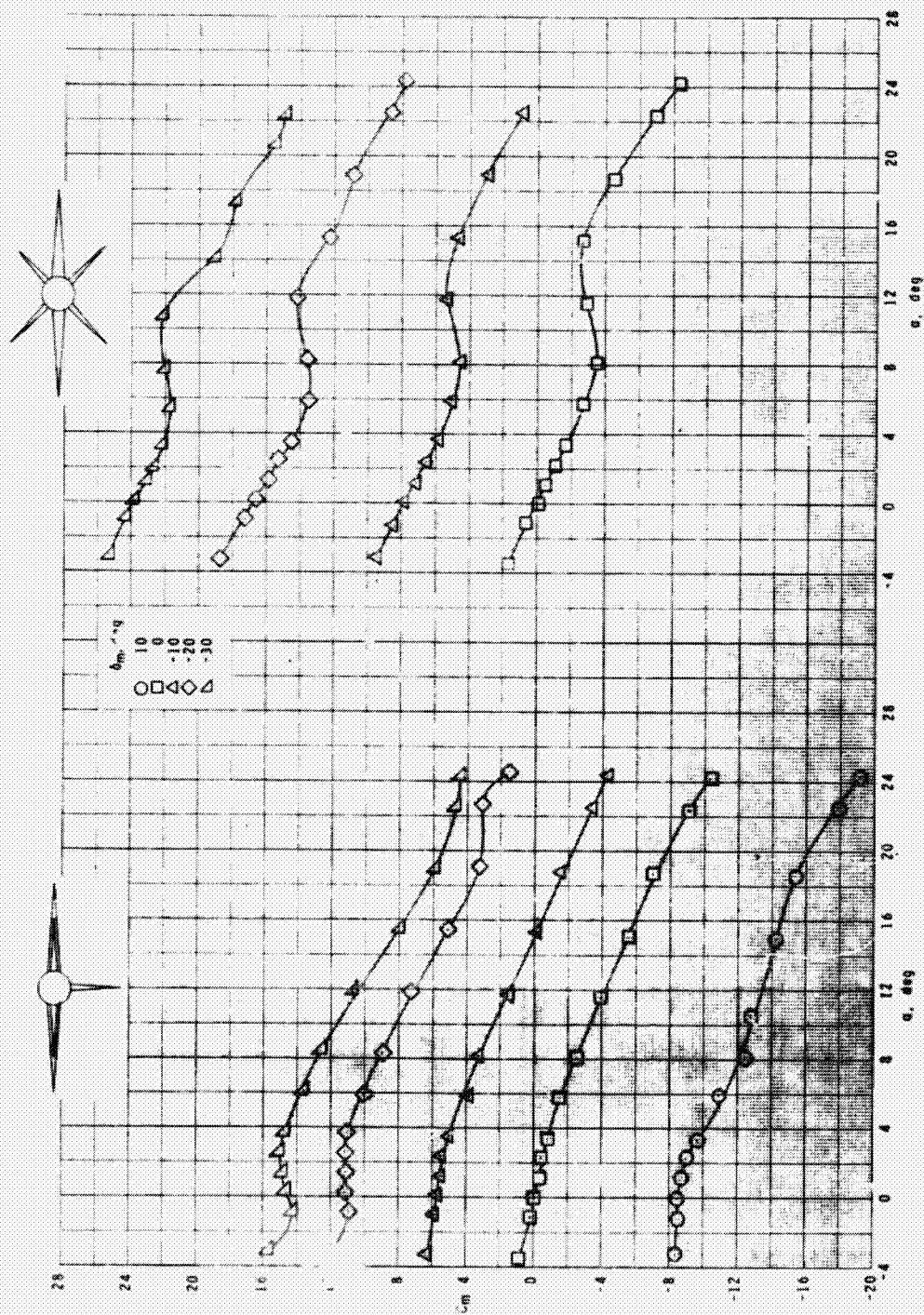
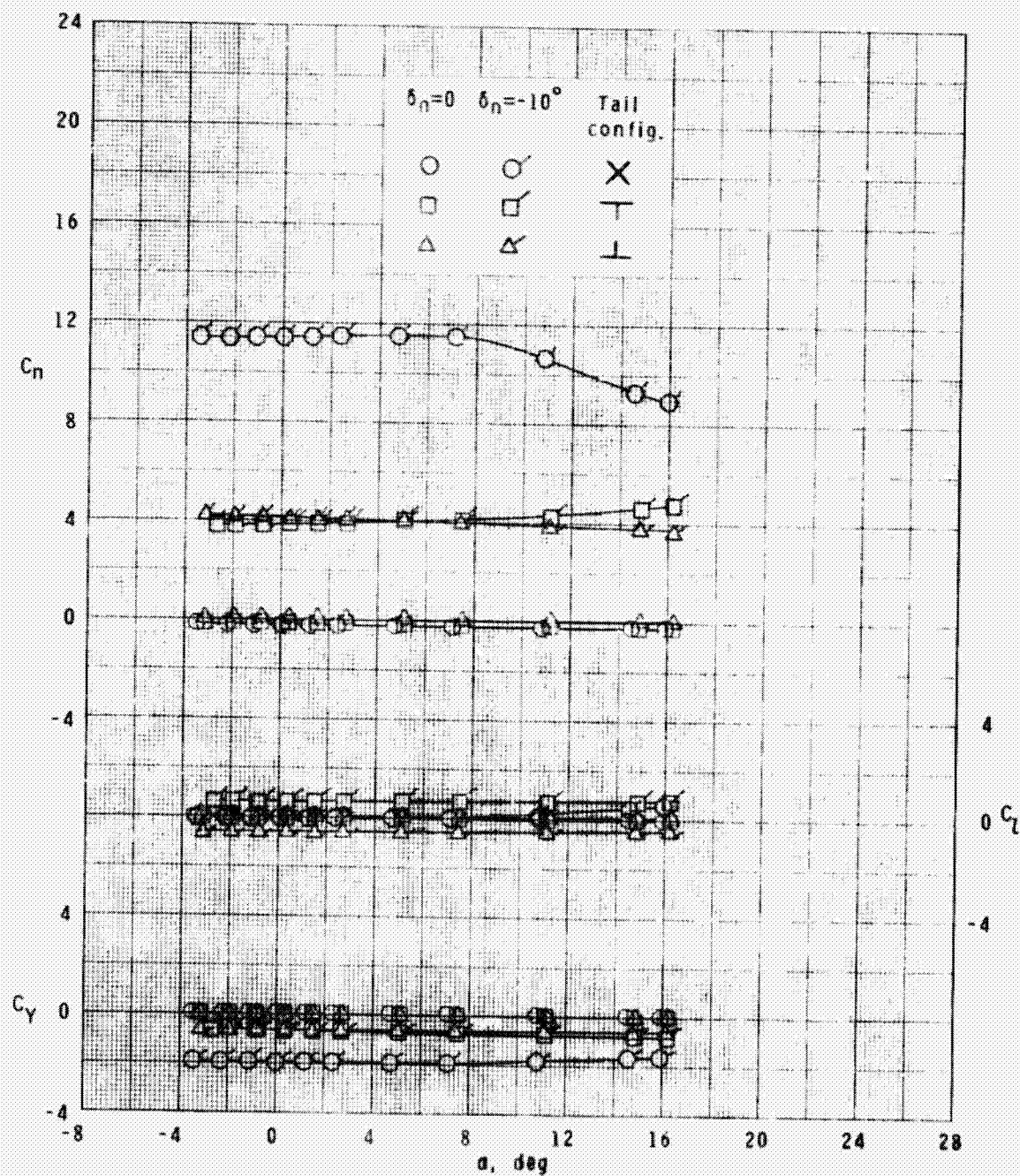
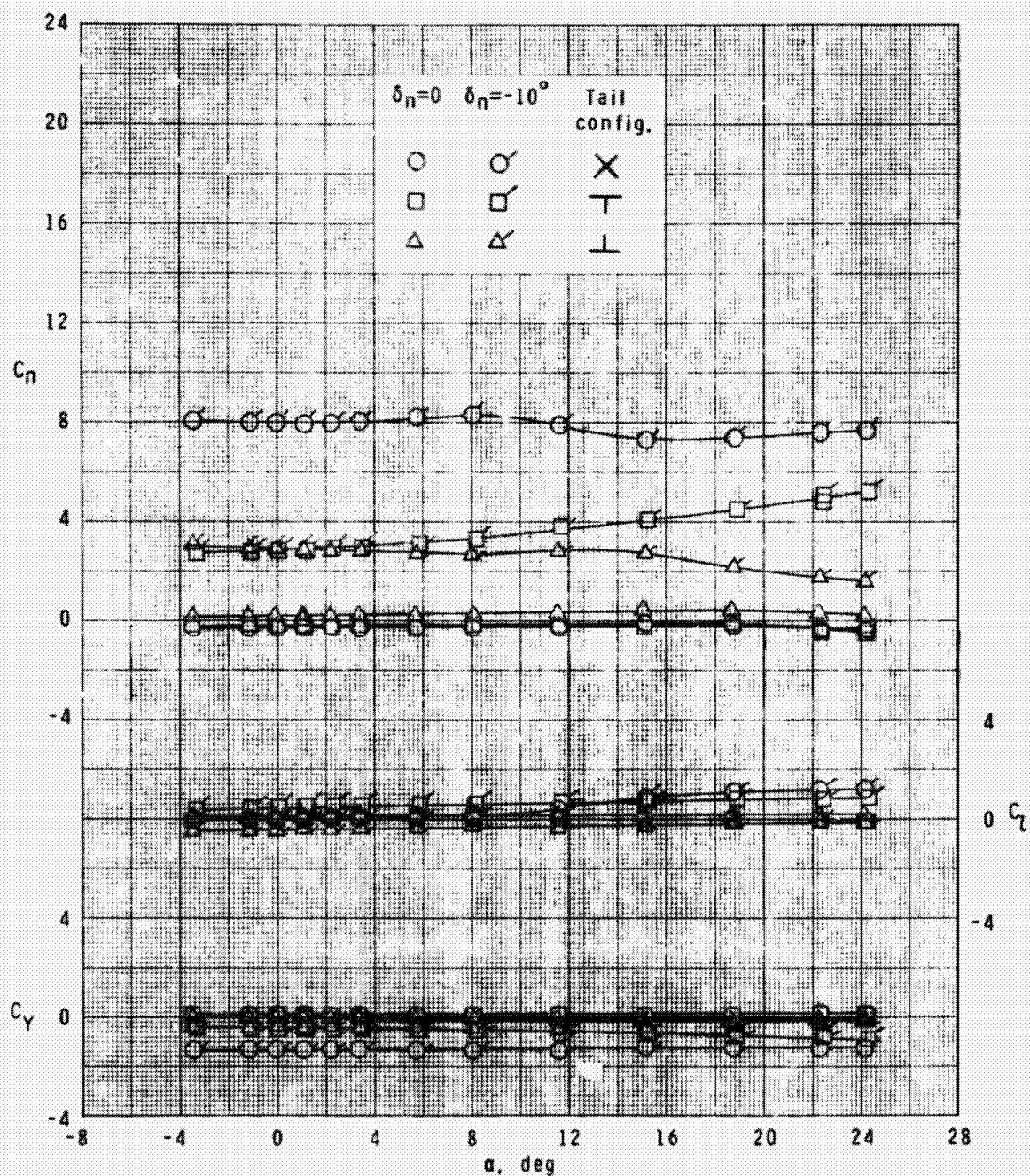


Figure 5. - Variation of pitch control characteristics with angle of attack; $M=2.36$.



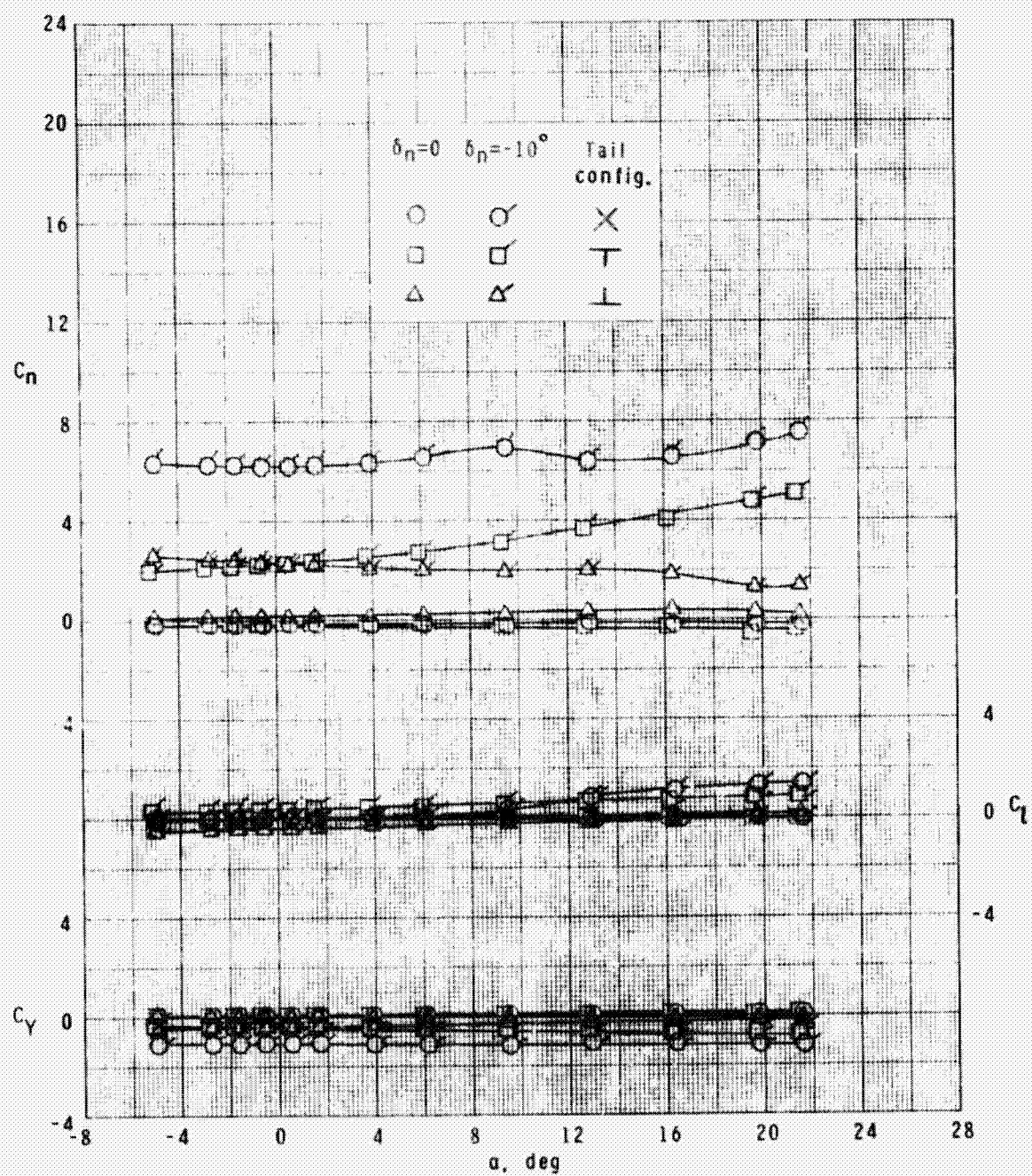
(a) $M=1.90$.
Figure 6 -Yaw control characteristics.

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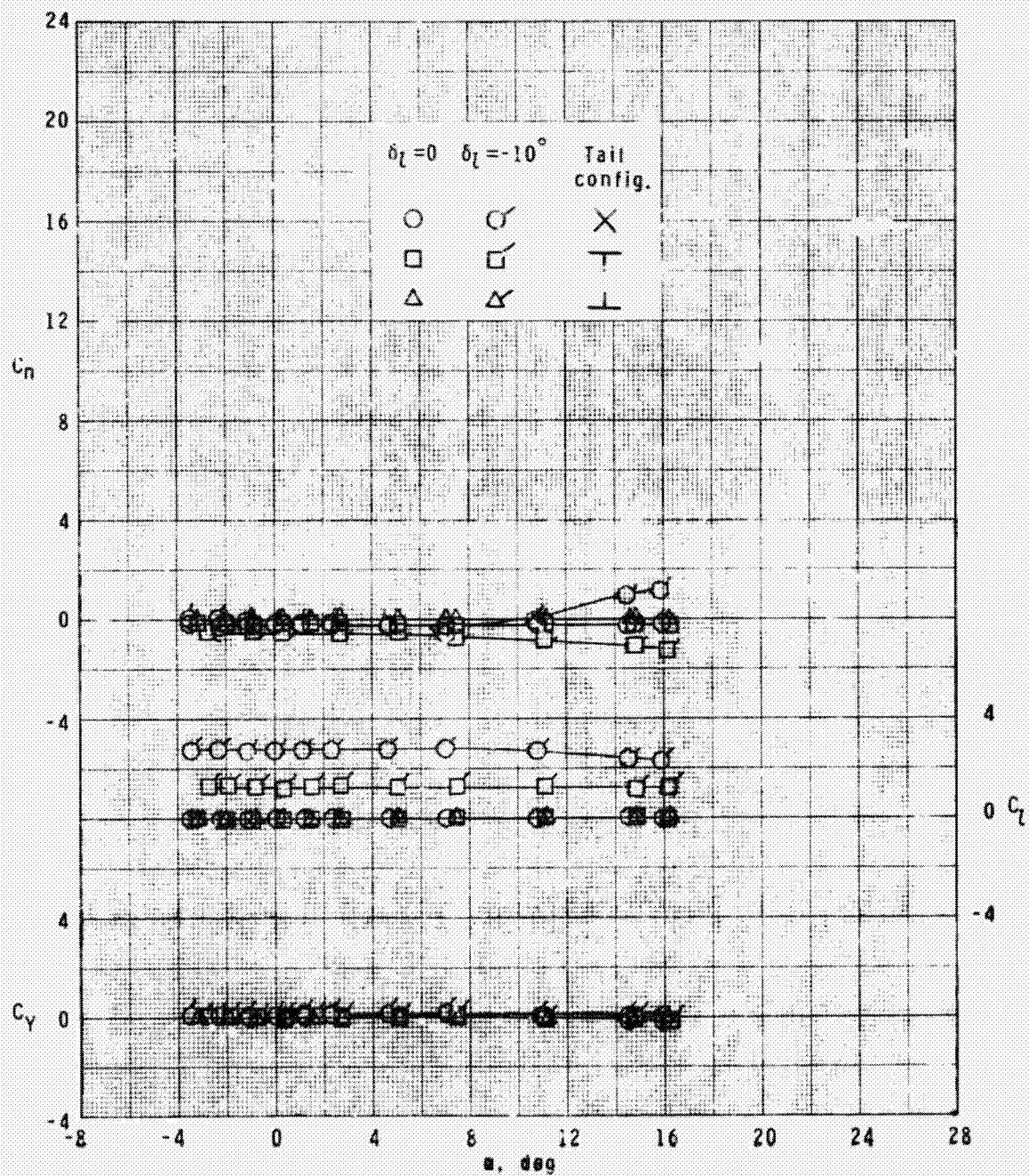
(b) $M = 2.36$.
Figure 6.-Continued.

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(c) $M=2.86$.
Figure 6.-Concluded.

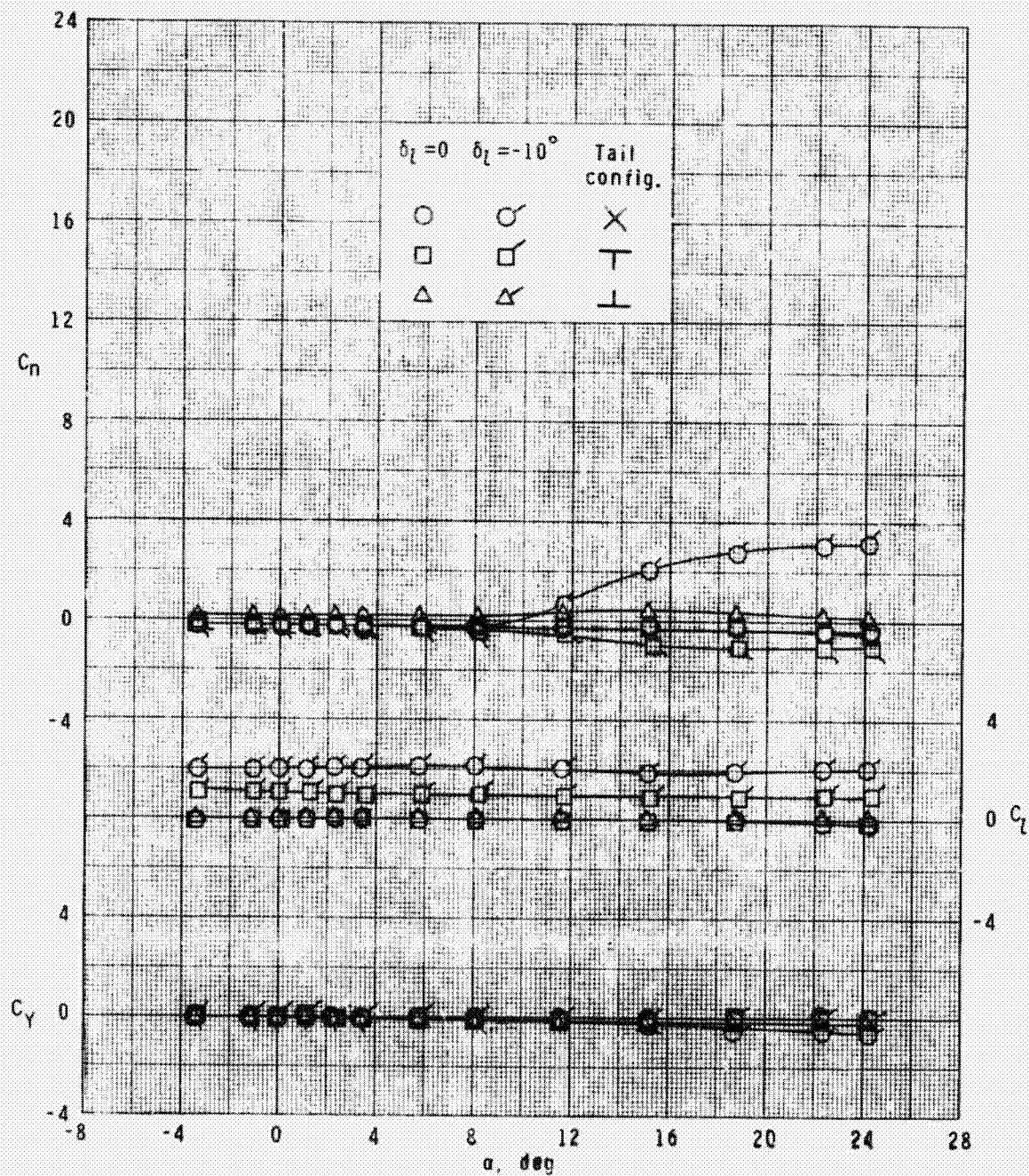
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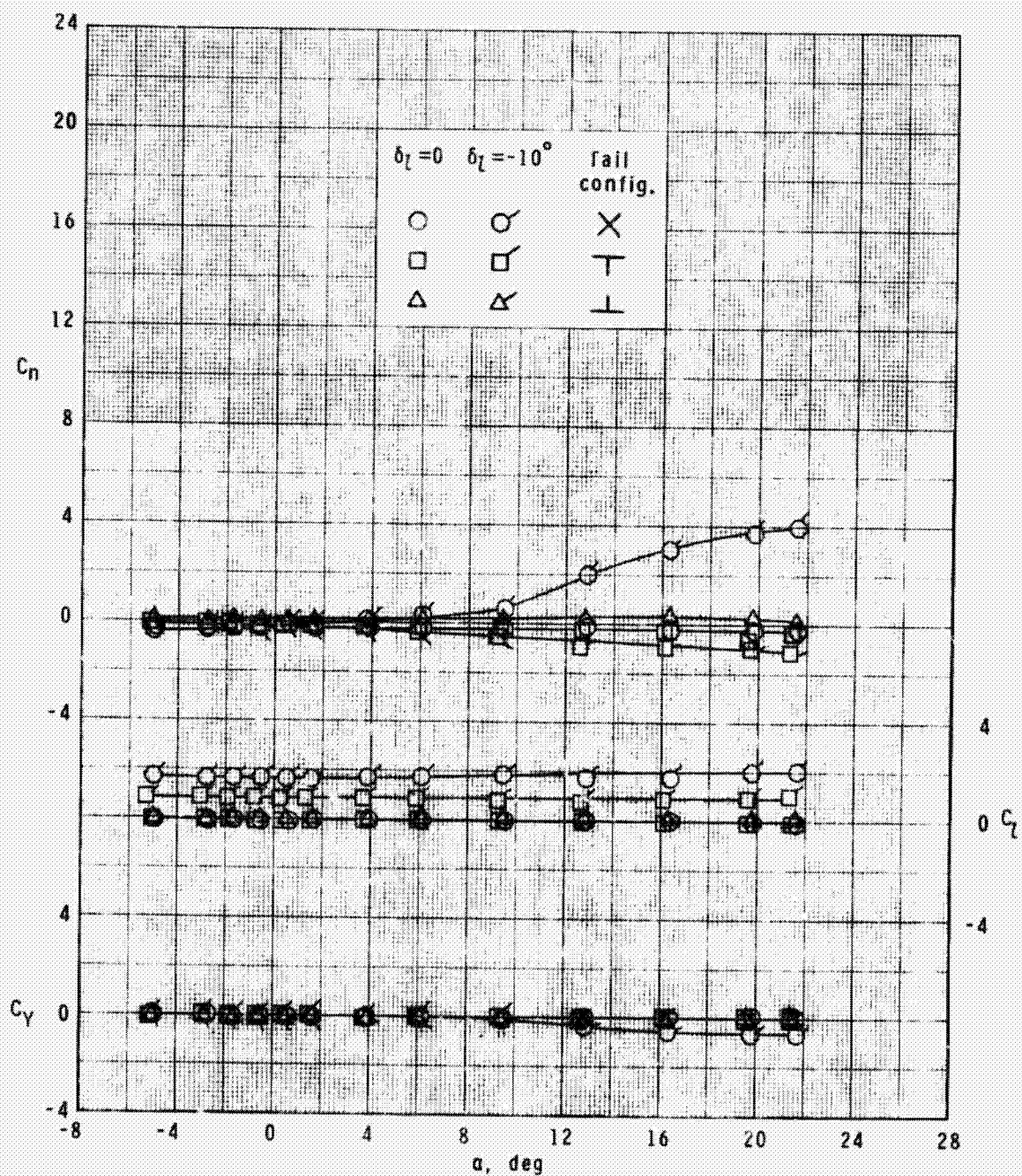
(a) $M=1.90$.

Figure 7.-Roll control characteristics.

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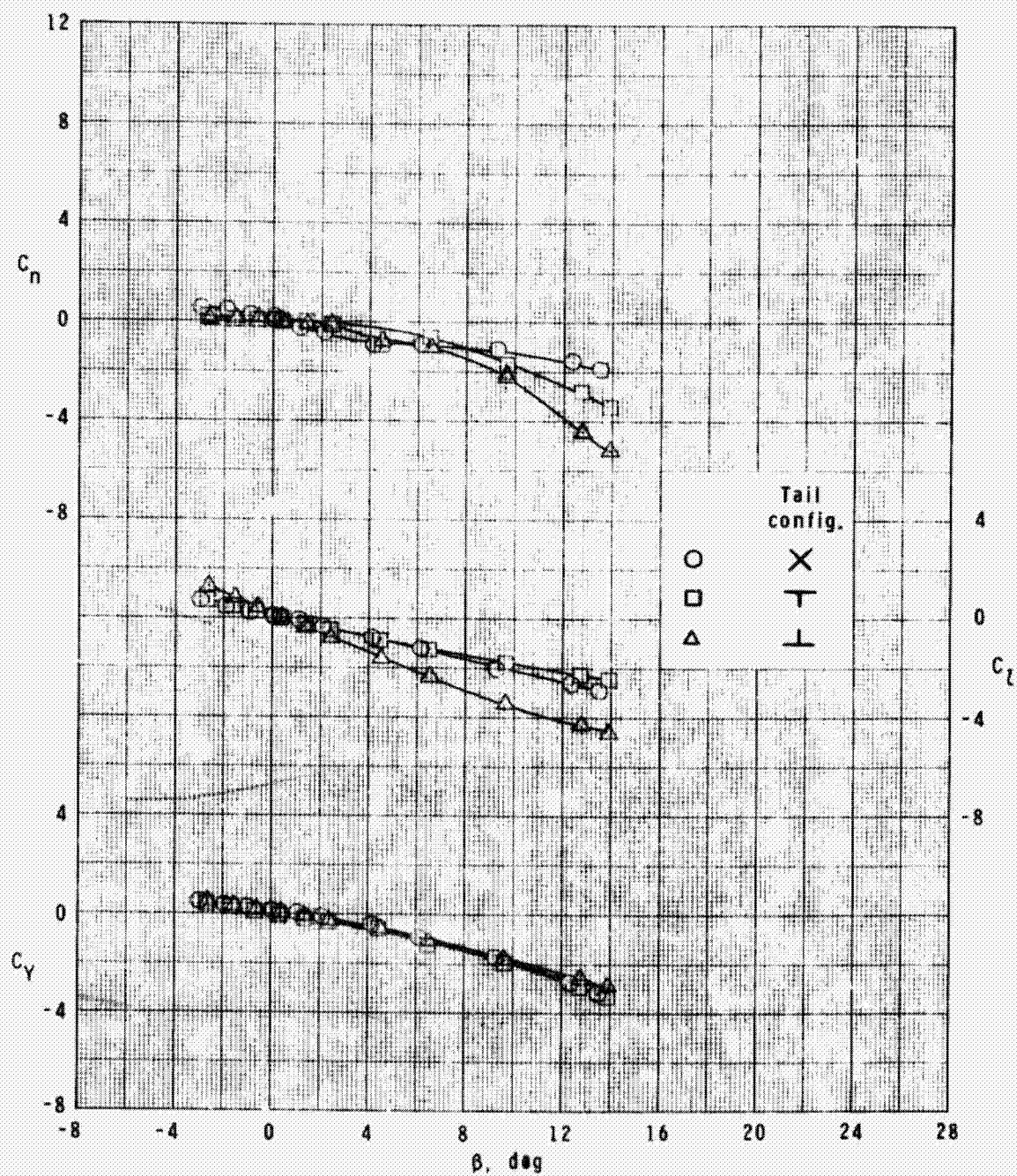


(b) $M=2.36$.
Figure 7.-Continued.



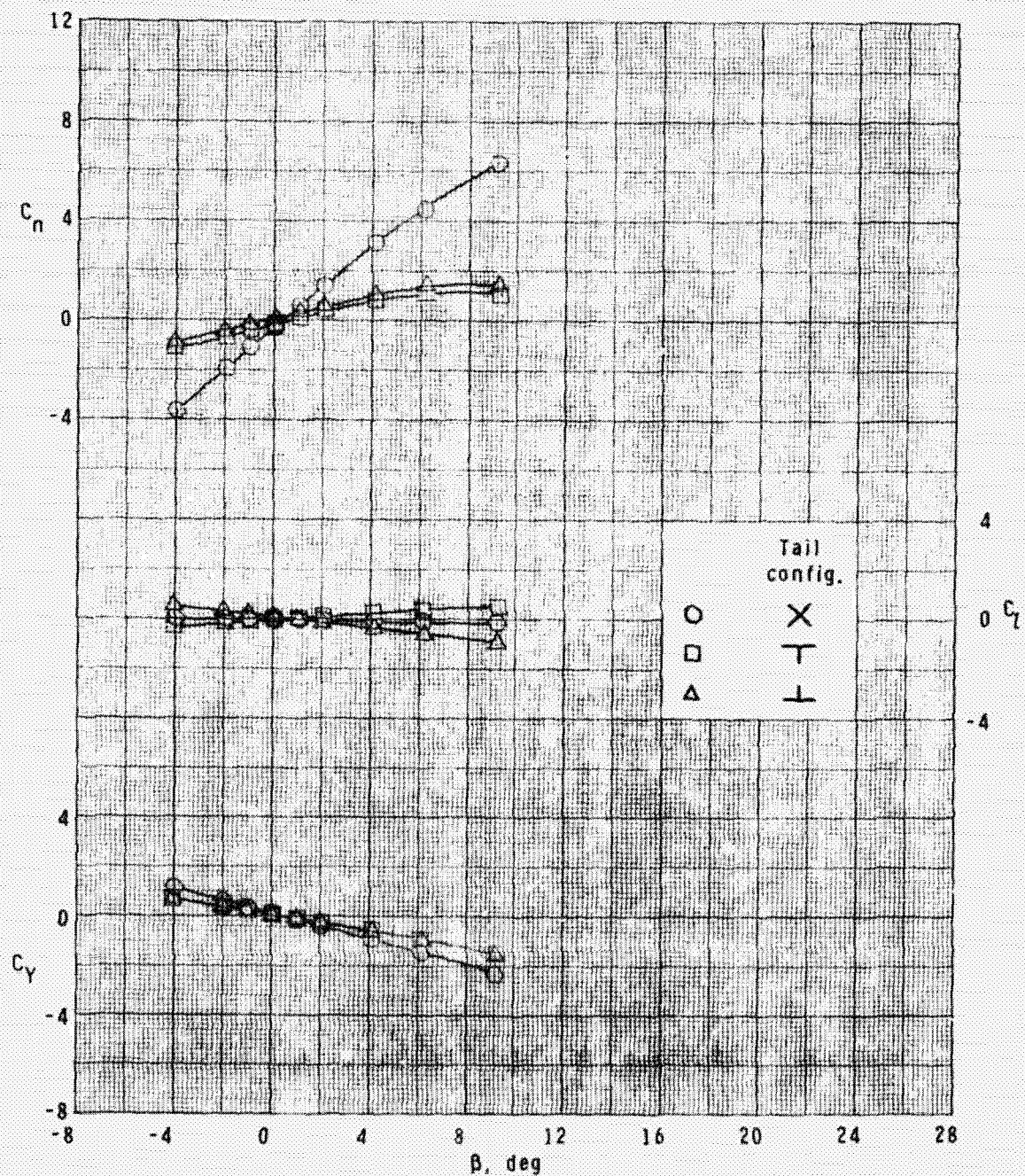
(c) $M=2.86$.
Figure 7.-Concluded.

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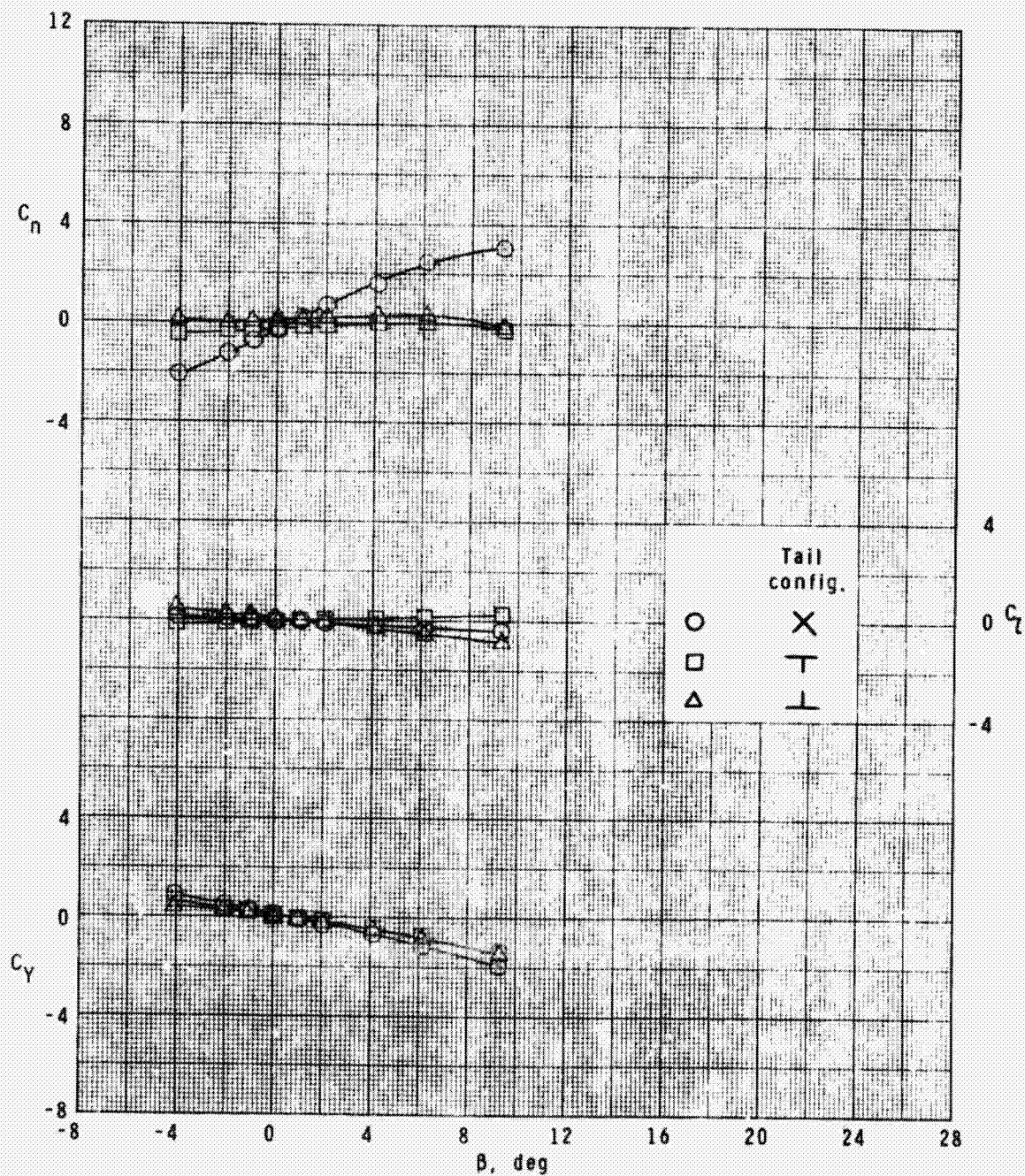
(b) $\alpha_{nom} \approx 10^\circ$.
Figure 8.-Concluded.

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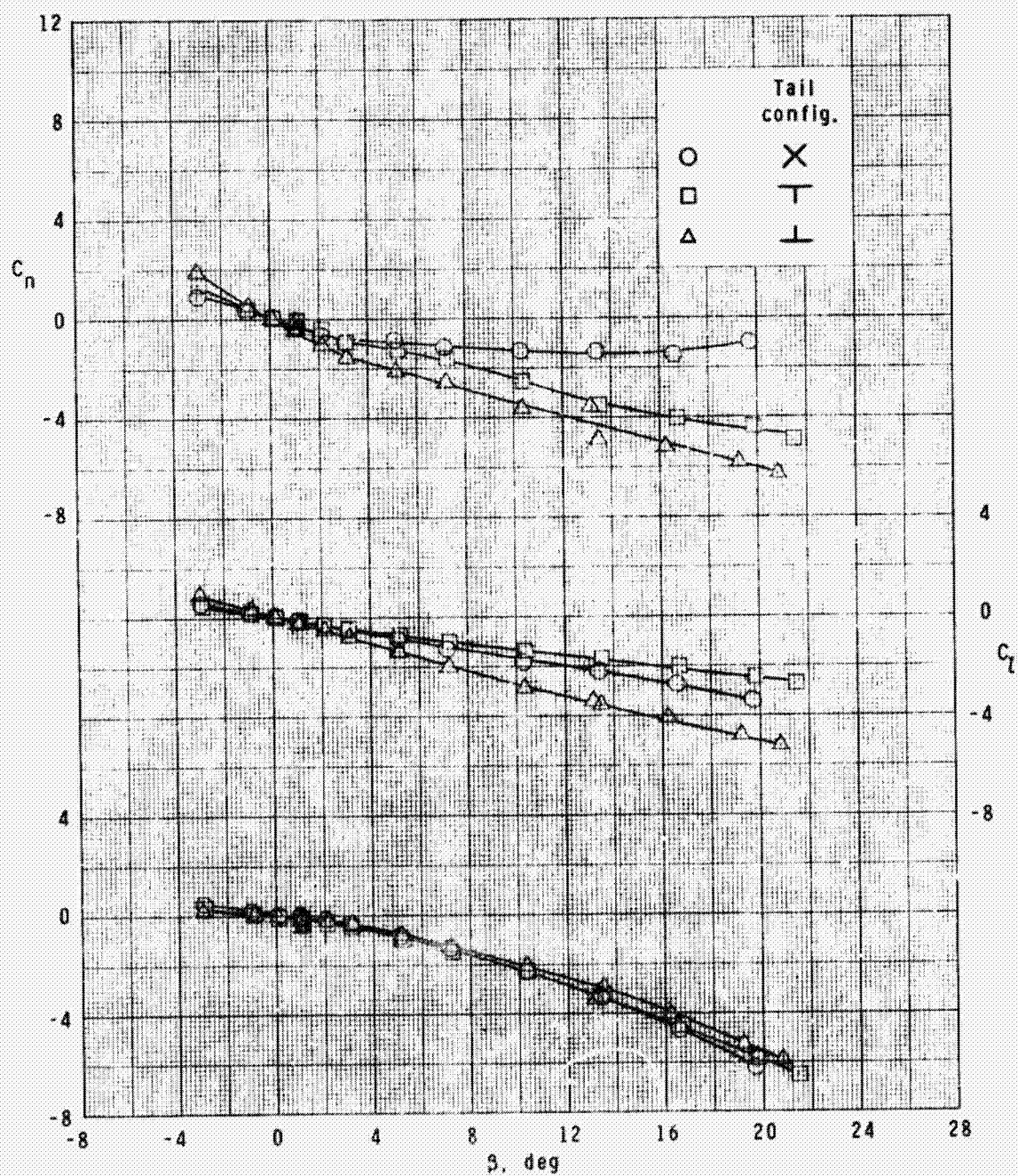
(a) $\alpha_{nom} = 0^\circ$.
Figure 8.- Aerodynamic characteristics in sideslip, $M=1.90$.

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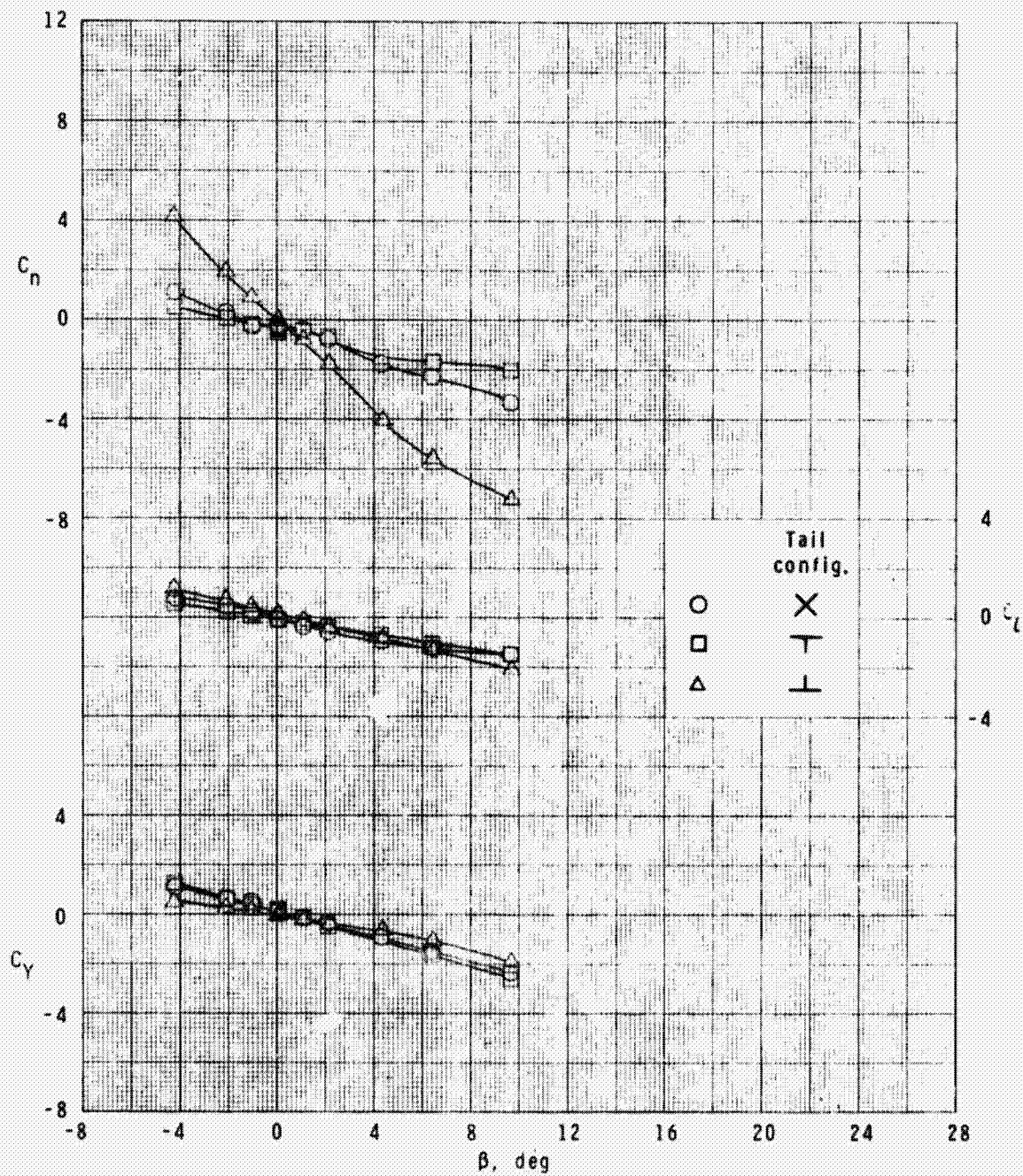
(a) $\alpha_{nom} = 0^\circ$.
Figure 9.-Aerodynamic characteristics in sideslip, $M=2.36$.

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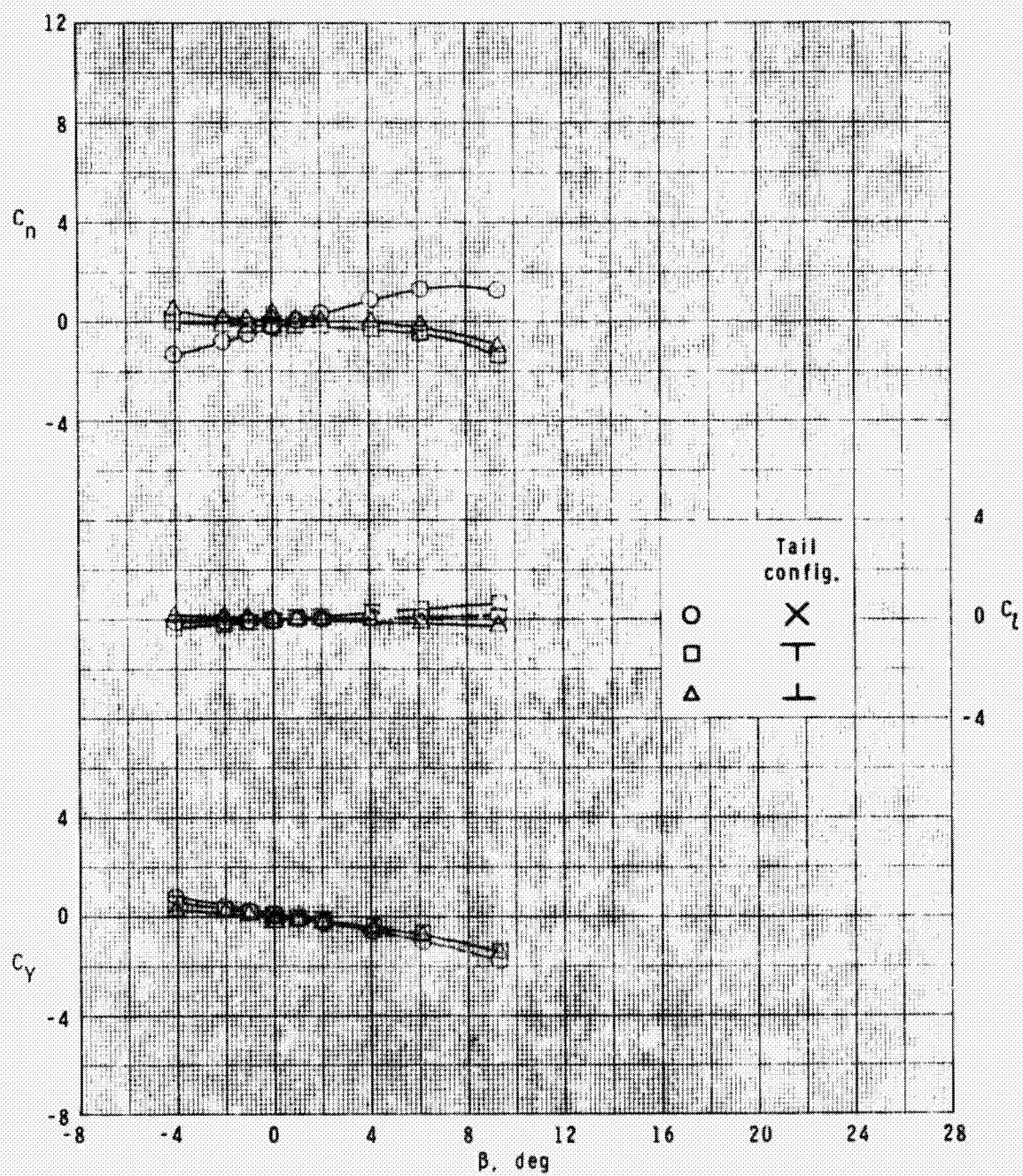


(b) $\alpha_{nom}=10^\circ$.
Figure 9.-Continued.

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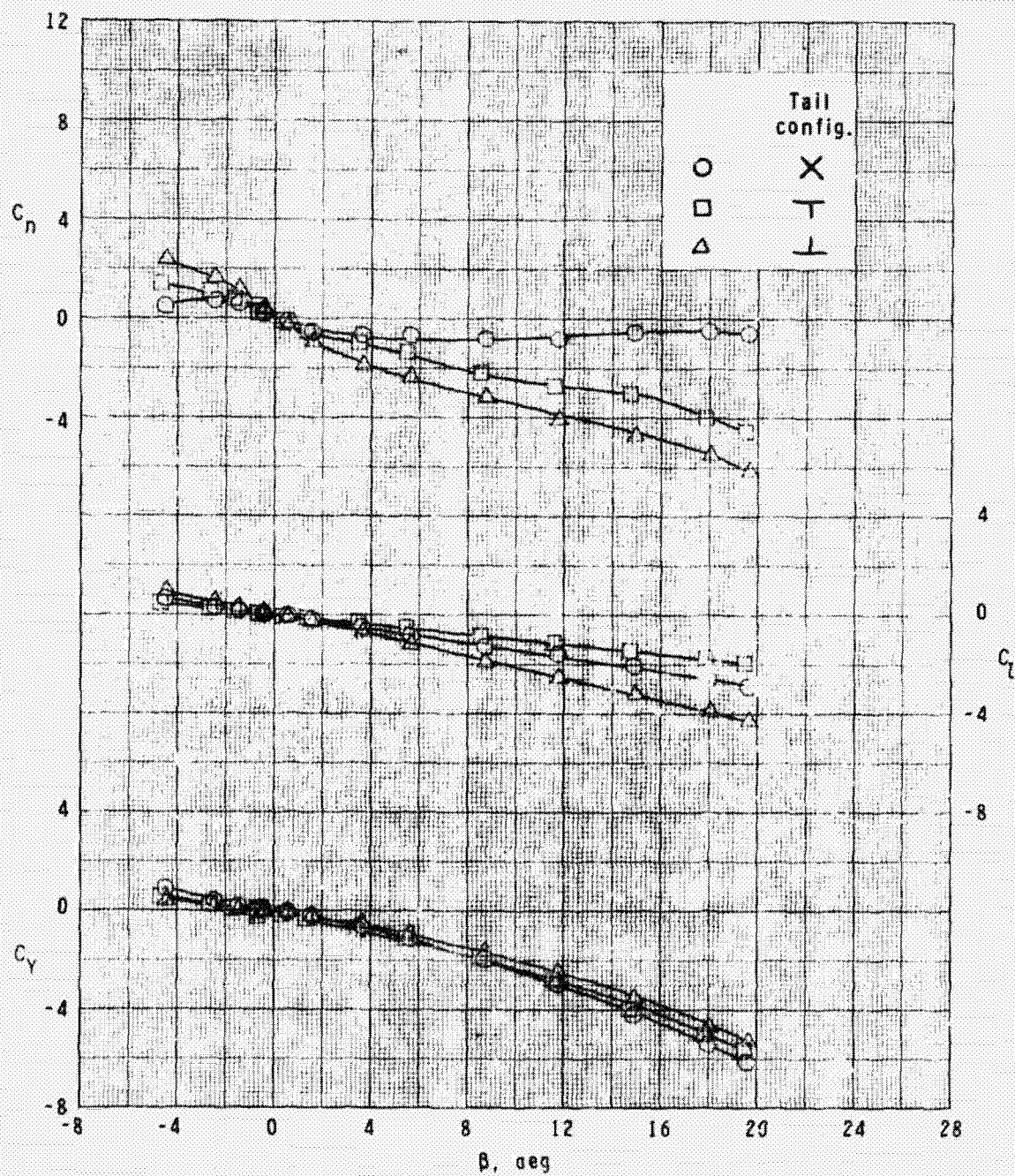


(c) $\alpha_{nm} = 20^\circ$.
Figure 9. - Concluded.



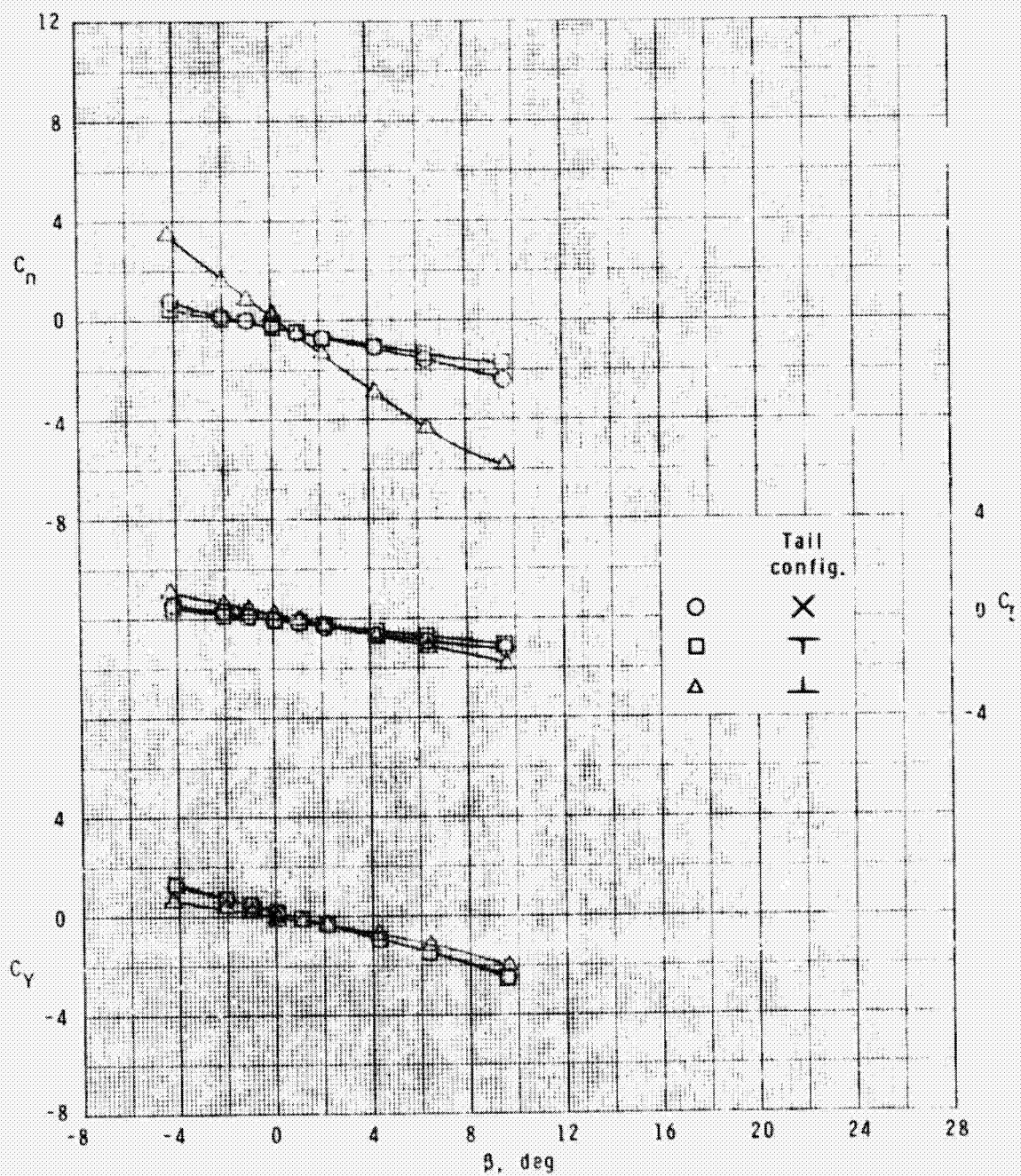
(a) $\alpha_{nom} = 0^\circ$.
Figure 10.- Aerodynamic characteristics in sideslip, $M=2.86$.

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(b) $\alpha_{nom} = 10^\circ$.
Figure 10.-Continued.

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(c) $\alpha_{nom} = 20^\circ$.
Figure 10.-Concluded.